UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

CONTRIBUTIONS

TO THE

GEOLOGY OF MAINE

BY

HENRY S. WILLIAMS

AND

HERBERT E. GREGORY

WASHINGTON

GOVERNMENT PRINTING OFFICE

1900

CONTENTS.

ILLUSTRATIONS.

LETTER OF TRANSMITTAL.

YALE UNIVERSITY,

New Haven, Conn., September 19, 1899.

SIR: I have the honor to transmit herewith a report including the following Contributions to the Geology of Maine, viz: Part I, The Paleozoic faunas of Maine, by Henry S. Williams; Part II, Geology of the Aroostook volcanic area of Maine, by Herbert E. Gregory; and Part III, List of localities of outcrops of Paleozoic and igneous rocks in Aroostook County examined in the years 1897 and 1898, by Henry S. Williams; and have to request that it be published as a bulletin of the Survey.

Yours, respectfully,

HENRY S. WILLIAMS.

Hon. CHARLES D. WALCOTT,

Director U. S. Geological Survey.

PREFACE.

The investigations reported upon in this bulletin were begun primarily for the purpose of ascertaining the facts regarding the local modification of the Devonian and Silurian faunas in the eastern province of North America. They were authorized by the Director of the Survey in a letter dated June 16, 1897, in the words: "Your special work will be the investigation of the Paleozoic rocks and fossils of eastern and northeastern Maine."

The Canadian Survey had already reported upon the Anticosti and Gaspé series, from the region beyond Maine to the east. In Nova Scotia the Arisaig and Nictaux series present another phase of the problem. Hitchcock, Shaler, and others, and, in Canada, Billings, Bailey, McInnes, Ells, and Ami, have gathered information here and there regarding the faunas occasionally met with in the region. It seemed greatly to be desired that careful collections should be made in the Maine territory, to serve as a basis for comparison between the typical expression of the Paleozoic faunas in New York State and those described from the eastern provinces of Canada, and also as a means of comparing the American with the European phases of the Paleozoic. Ten years ago a beginning was made toward carrying out this plan, and collections were made in Somerset County (see fig. 1, p. 12). They alone did not throw much light upon the succession of Paleozoic faunas, and the work was resumed in 1897.

The field work in Aroostook County (see fig. 1) was done in the summer months of 1897 and 1898; in the former year by Dr. Herbert E. Gregory and myself and in the latter year by Dr. Gregory alone. In 1897 the localities north of the Aroostook were examined by me, those south of the river partly by Dr. Gregory alone, and the more northern townships by both of us together. In 1898 Dr. Gregory reexamined the volcanic area, to gather special facts for his part of the report (Part II). The petrographic study of the materials gathered was made under the direction of Prof. L. V. Pirsson in the mineralogical laboratory of Yale University. The results of his investigations were written by Dr. Gregory substantially in the form now appearing as Part II of this report, and were offered to and accepted by the faculty of the graduate department of Yale University for the degree of doctor of philosophy, given him in June, 1899.

The collections from Somerset County were made for the Survey in 1889 by Mr. Gilbert Van Ingen under my direction. Several collections of fossils, including the fine one from Square Lake, were made by Mr. Olaf O. Nylander, and secured for the Survey.

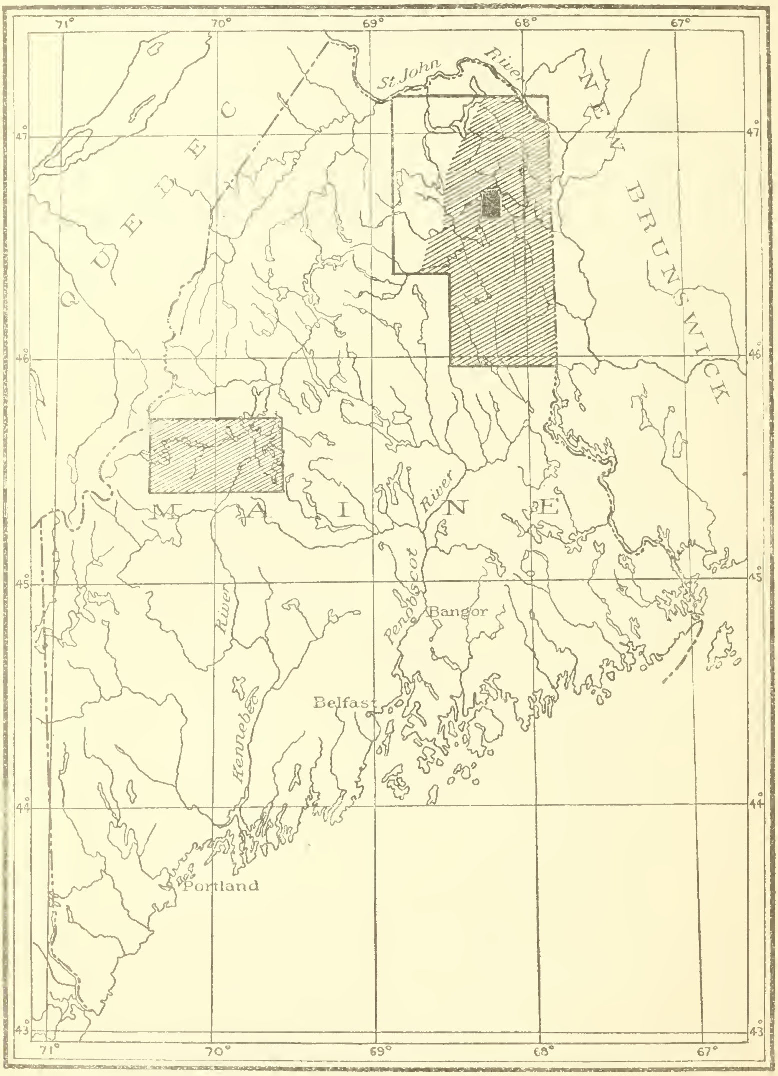

FIG. 1.—Index map showing the locations described in this report. The larger shaded area on the right is the Aroostook County area referred to in Parts I, II, and III. The small black rectangle in the midst of the shaded area is the volcanic district reported upon in Part II. The smaller shaded area on the left side is the Somerset County area.

All the fossils have been examined by me personally, and the report on the faunas (Part I) constitutes a preliminary report on the geologic results of such study. Many of the species are new species or varietal

forms. Their paleontologic description is reserved for future publication.

A few well-defined formations, with their faunas, have been elaborated. The fossils, though few and imperfect, and in almost every case varying more or less from the typical species familiar to us from the sections in the interior of the continent, have been identified with sufficient certainty to make their general stratigraphic position evident.

In this preliminary report the listing of species has been made primarily with the view of bringing out the geologic facts. In many cases, as just stated, the forms do not exactly agree with any of the described species of the New York or interior region. In such cases identification has been given with the species to which the resemblance is closest. When it is noted that a remarkable number of new species were found by Billings in both the Gaspé and the Square Lake faunas—differing at least varietally from any other known species in America or Europe—it will not seem strange that these Maine faunas should contain many species which can not be exactly identified with any that have been described. However, a few of the species of each fauna have been identified with known species, making the stratigraphic position evident. To determine the horizons with greater precision, a thorough biologic study of each fauna and its comparison with typical European as well as American collections will be required.

In lists of species here given, the sign cf. (*confer*) is frequently employed to indicate that the name used is that of a species already described with which the specimen named closely agrees but is not strictly identical. For the same reason no attempt is made to give the name of the true author of the species. The lists are given for geologic rather than biologic purposes.

Lists of faunas obtained from Maine, New Brunswick, and a few other localities, and already reported upon, are introduced, as given in the original reports, for reference in correlating the terranes. The typical New York faunas are not reproduced, as they may be easily obtained from standard reports. The collections are all numbered and the fossils are in process of paleontologic study for final description and illustration. Many of them are already figured. Samples of the Square Lake fossils are given on Pls. I and II (pp. 64, 66). The original figures reproduced on these plates were made by a new, patented photographic process, directly from the specimens, by Mr. N. W. Carkhuff.

At the beginning of our investigations I had expected to obtain sufficient knowledge of the stratigraphy of the region to interpret the true succession of the various terranes. The remarkable scarcity of fossils, the heavy sheet of drift, and the general fractured, disturbed, and semislated state of the rocks have left little reliable evidence of original structure to work on. It has been impossible, therefore, with

present knowledge, to determine the precise areal distribution of the several formations, although the facts as to the structure and the stratigraphic sequence of the rocks are given whenever they are conclusive. More detailed study of the region must be made before the areal geology can be mapped with any degree of precision.

The map (Pl. IV) prepared by Dr. Gregory indicates the general areal distribution of the clastic rocks in Aroostook County, so far as we have observed them. The belts of similar rock have a general northeast-southwest trend. The Aroostook limestone is on the east, the arenaceous limestones and shales are next westward, and the more sandy Sheridan sandstones are in the western part of the area; but this does not accurately express the distribution of the formations, for in the region marked as sandstone are found not only the Ashland limestone areas, but slates that are undoubtedly older than the Sheridan sandstone, which contains pebbles of apparently these same slate rocks.

Because of the uncertainty regarding the true sequence of the clastic formations, Dr. Gregory has classified them (in Part II) purely on petrographic characters. This gives the facts which will make their areal mapping possible, but leaves their classification on a stratigraphic basis to be completed when further evidence regarding the sequence has been obtained.

The description of the physical and lithologic characters of the rocks and geologic formations will be found in Part II. A list of all the localities in Aroostook County examined by Dr. Gregory and myself is given in Part III.

The collections here reported upon were made by Gilbert Van Ingen, Olaf O. Nylander, Herbert E. Gregory, and myself, and are now the property of the United States Geological Survey. We are indebted to Mr. Nylander for pointing out numerous localities along the roads, in out-of-way places, where he had discovered outcrops, and we are particularly indebted to him for knowledge of several important exposures containing fossils. Mr. Nylander is a keen observer, and deserves great credit for the discovery of fossil localities which it would have taken much time and labor to locate without his preliminary work.

For many courtesies we are indebted to the officials of the Bangor and Aroostook Railroad, and the State land office, and to numerous landowners whose farms we invaded in the course of our surveys, and who, in many cases, took considerable pains to promote our investigation.

H. S. W.

CONTRIBUTIONS TO THE GEOLOGY OF MAINE

Part I. THE PALEOZOIC FAUNAS OF MAINE

A PRELIMINARY REPORT UPON THE PALEOZOIC FAUNAS ALREADY KNOWN AND UPON NEW FAUNAS RECENTLY COLLECTED FROM AROOSTOOK COUNTY

BY

HENRY S. WILLIAMS

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ILLUSTRATIONS IN PART I.

CONTRIBUTIONS TO THE GEOLOGY OF MAINE.

PART I. THE PALEOZOIC FAUNAS OF MAINE.

By Henry S. Williams.

CLASSIFICATION OF THE PALEOZOIC TERRANES OF AROOSTOOK COUNTY.

Recent investigation of the rocks of the northern part of Aroostook County has brought to light a few facts regarding the stratigraphic terranes, which may be stated with some degree of precision.

There are a few well-marked groups of rocks which are distinguishable by their lithologic characters, and the relative age of which is determined by their contained fossils. The order which the present knowledge of the faunas seems to indicate is as follows:

9. Mapleton sandstone	= Devonian.
8. Moose River sandstone	
7. Chapman sandstone	= Silurian.
6. Square Lake limestone	
5. Ashland limestone	
4. Ashland shales	
3. Sheridan sandstone	
2. Graptolite shales	
1. Aroostook limestone	

Below the Aroostook limestones are slates, which it is believed are of Cambrian age, but positive evidence of the age is wanting.

The lower seven belong to the Silurian; the upper two to the Devonian. The paleontologic evidence is clear in placing 1–5 below the Lower Helderberg horizon of the New York series.

The Aroostook limestone, on both stratigraphic and paleontologic grounds, is believed to be older than any other of the terranes mentioned in this list.

The Ashland limestone, Ashland shales, and Sheridan sandstone are faunally closely associated, and belong together as the representatives of the Clinton-Niagara of the New York standard.

The Graptolite shales, the writer believes to be of Clinton age, but their stratigraphic position in the Maine series is not satisfactorily established. They may belong in the midst of the series 3, 4, 5, or even above them; more evidence will be needed to determine their position with certainty.

The Chapman sandstone fauna is younger than the Square Lake fauna; the present opinion is that it corresponds closely with the Lower Oriskany of the New York and interior series. The identification of the fauna with Honeyman's Zone D Arisaig and with the "Tilestone" fauna of Wales establishes its place at the top of the Silurian (see Am. Jour. Sci., 4th series, Vol. IX, p. 203).

The Moose River fauna is a facies of the Eodevonian, and represents the Oriskany.

The Mapleton sandstone is the representative of the higher parts of the Gaspé sandstone, and is the Old Red sandstone facies, not expressed in New York until a point higher up, in the Catskill sandstone, is reached.

Besides these terranes, determinable by their fossils, there are slates and crystalline rocks, the precise age of which is undetermined. The slates are presumably Cambrian or pre-Cambrian.

In the paper prepared by H. E. Gregory (Part II) the several terranes are described from a lithologic and petrographic point of view. In the following pages (Part I) the faunas are described and grouped together in the combinations suggested by their contents and by the character of the rocks containing them. In the two papers combined are presented the preliminary results of the writers' investigations, so far as they concern the interpretation of the geology of the regions studied. Many problems are raised which will require further petrographic and paleontologic investigation for their solution.

For purposes of comparison the typical sections of the Silurian and Devonian of the Canadian survey, including the Anticosti Island and the Gaspé Peninsula, are important. The interpretation of these sections was made by Sir William Logan, and was reported in a summary form in the Geology of Canada. The sections of particular importance, for the present purpose, are Nos. 10 and 11 of Pl. IV.

Section No. 10 is described in the text as follows:[1]

This line extends from Ste. Anne des Monts, on the south bank of the Gulf of St. Lawrence, in a south-southeast direction across the Peninsula of Gaspé to the mouth of the Great Cascapedia River on the Bay of Chaleurs. Commencing with the Quebec group, it crosses the Shickshock Mountains, which are formed of altered Sillery rocks, and the Barn-shaped Mountain, an intrusive mass of trachytic granite. It then traverses a great breadth of Upper Silurian, which rests unconformably upon the Quebec rocks, and presents two subordinate basins, in both of which appears the great Gaspé sandstone formation of Devonian age. This, in the southern basin, on the Bay of Chaleurs, is seen to be unconformably overlaid by the Bonaventure formation belonging to the Carboniferous period. The whole length is 68 miles.

[1] Geol. Survey Canada. Report of progress from its commencement to 1863. Atlas of maps and sections, 1863, Pl. IV, and text of explanations, p. 26.

The classification is given in the index of the chart as follows:

22.	Bonaventure			Carboniferous.
19.	Gaspé sandstones =	Chemung		Devonian.
17.		Oriskany		
16.	Cape Gaspé limestones =	Lower Helderberg	= Gaspé limestones.	
15.	Port Daniel limestones =	Onondaga?		Upper Silurian.
12.	Chatte River limestones =	Clinton		Middle Silurian.
6.	Sillery = Chazy	= Quebec		Lower Silurian.
5.	Calciferous			
	Trachytic granite			Intrusive.

Section No. 11 is defined as follows:[1]

This line from the Laurentian of the main land to the north of the Mingan Islands, on the north shore of the Gulf of St. Lawrence, passes southeast across the water of the gulf to Anticosti, thence southwest across this island to Gaspé Bay, and finally south to Cape d'Espoir, on the bay of Chaleurs. Showing portions of the Lower Silurian rocks in the Mingan Islands, it exhibits the Middle Silurian in Anticosti, and the rocks of the Quebec group, brought up by a fault near Cape Rosier, in Gaspé. Reposing uncomformably upon these we have, as in the last section, a great basin of the Gaspé limestones and sandstones, exhibiting several faults and undulations, and holding in two of the subordinate basins portions of the unconformable Bonaventure conglomerate. The length of this section is 161 miles.

The index of the chart is as follows:

22.	Bonaventure			Carboniferous.
19.	Gaspé sandstones	Chemung		Devonian.
17.		Oriskany		
16.	Cape Gaspé limestones	Gaspé limest.	Lower Helderberg	Upper Silurian.
15.	Port Daniel limestones; L'Anse a la Veille limestones		Onondaga (Ludlow)	
12.	Southwest Point limestones	Anticosti	Clinton	Middle Silurian.
11.	Junction Cliff limestones		Medina	
10.	Hudson River			Lower Silurian.
9.	Utica			
8.	Trenton			
7.	Birdseye and Black River			
6.	Chazy	Quebec		
5.	Calciferous			
4.	Potsdam			
1.	Gneiss			Laurentian.

The classification adopted on the general map is given on page 18 of text, and is in part as follows:

22.	Bonaventure conglomerate.		
21.	Lower Carboniferous limestone.		
20.	Old red sandstone	Gaspé sandstone	Devonian.
19.	Chemung and Portage		
18.	Hamilton		
17.	Oriskany and Corniferous		
16.	Lower Helderberg	Gaspé limestone	Upper Silurian
15.	Onondaga		
14.	Guelph		Middle Silurian.
13.	Niagara		
12.	Clinton		
11.	Medina and Oneida.		
	Etc.		

[1] Geol. Survey Canada. Report of Progress. Atlas. 1863. Pl. IV and text, 7 explanations, p. 26.

The classifications and correlations of these Anticosti and Gaspé formations remain substantially as they were given in this report in 1863.

In the body of the work the Anticosti group is defined as follows:[1]

The remaining portion of the island is occupied by newer rocks, to which the name Anticosti group has been given. Their position in the geologic series is that occupied by the Oneida conglomerate, the Medina sandstone, the Clinton group, and the Niagara group of the New York geologists; but these subdivisions, although apparent in the western basin, disappear in the Anticosti strata, which are lithologically unlike their equivalents in western Canada.

This last remark also applies to the corresponding formations of Maine. The Maine terranes, numbered 1 to 5 in the list already given, although their age is clearly Eosilurian, differ from the New York terranes both in their stratigraphy and in the composition of the faunas.

The limestones of Cape Gaspé appear to be a great development of strata of the age of the Lower Helderberg group. The fossils at the summit, however, bear a striking resemblance to those of the Oriskany formation, with which several of them are identical. It appears probable, therefore, that we have here a passage from the Lower Helderberg to the Oriskany, and the latter formation may be more especially represented by the lower part of the Gaspé sandstones. The organic remains discovered in these sandstones are as yet too few to enable us to separate the series into distinct members. We have already mentioned that a species of Rensselæria, identical with or closely resembling *R. ovoides*, which occurs in the upper part of the limestones, is met with at 1,100 feet above the base of the sandstone series. This fact, together with the constancy in the lithological characters of the latter, makes it not improbable that at least this lower portion of the sandstones will ultimately be classed with the Oriskany formation.

In the land plants there appears to be but little difference from the commencement of the series to the base of the red sandstones, a thickness of over 5,000 feet. These strata present analogies with the whole series of formations in New York, from the Marcellus shales to the summit of the Chemung sandstones, in all of which, according to Dr. Dawson, are found several of the species of plants that occur in the Gaspé sandstones. The whole of these 5,000 feet resemble, lithologically, the Portage and Chemung sandstones of New York, and it may hereafter be found that in this eastern part of the continent the Oriskany fauna, which occurs at the base of this Devonian series, merges gradually, toward the summit, into that of the Portage and Chemung group. In lithological characters the remaining upper 1,800 feet of the Gaspé series resemble the Catskill group of New York, which is regarded by Mr. Hall as the base of the Carboniferous system. As yet, however, no comparison can be made by fossils; those found in Gaspé being chiefly confined to a few obscure plants.[2]

On passing westward the formations lower than the typical Gaspé limestone of Cape Gaspé come into sight. "On the Chatte and Matanne rivers, on Lake Matapedia, and on the rivers Mētis and Rimouski, the lower portion of this series of limestones appears to belong to the Anticosti group."[3]

This connection of the representatives of the Clinton-Niagara series directly upward with those of the Lower Helderberg, without indi-

[1] Geol. Survey Canada. Report of Progress, 1863, p. 298.

[2] Op. cit., pp. 391, 403–404.

[3] Op. cit., p. 390.

cation of any rocks or faunas to be correlated with the Onondaga or Guelph, is confirmed by the Maine series of faunas and formations. As far west as St. Helens Island, Lake Memphremagog, and Dudswell, in Quebec Province, where the Silurian is recognized by occasional fossiliferous rocks, everything at present reported points to a geologic history in common with the Anticosti and Gaspé regions, and not in conformity with the events recorded west and south of Hudson River.

In classifying the Maine faunas, closer correlation is to be expected with the faunas of the eastern province than with the Appalachian or interior provinces. Not only do the Maine faunas agree in general sequence and composition with those of this eastern province, but this fact is of great significance in correlating American with European systems.

The boundary between the Silurian and Devonian systems was first made in the Welsh series, in which the transition was from calcareous sedimentation, with rich and purely marine faunas, into sandstones of great thickness containing land plants and fishes whose habitat was, presumably, fresh or brackish waters.

The New York section, from the Lower Helderberg limestones through the Oriskany, Cauda-galli, and Schoharie grits back again into limestones, does not pass out of marine conditions. In the Gaspé region, however, there is a complete change (as there was on the other side of the Atlantic Basin) at the point where the Oriskany fauna was evolved. In these Silurian faunas of the eastern province there is also much closer resemblance to the Wenlock-Ludlow series than is found in the faunas of the Appalachian province in New York. The correlation of the passage beds at the top of the Silurian of Wales is clearly to be recognized in the passage from the Gaspé limestones to the Gaspé sandstones of the eastern province of America. This Gaspé transition is also to be traced with precision to the horizon of the introduction of the Oriskany fauna into the basins farther west and southwest, in which no direct passage into Old Red sandstone condition is apparent.

We have thus in America a means of determining where the Silurian boundary belongs in purely marine series of beds and among marine faunas of unbroken succession. The Lower Helderberg in the interior of the American continent, as the Koniprusien F2 fauna in the Bohemian Basin of Europe, is closely related in its species to what succeeds, because there was no radical disturbance of the conditions of marine life. Nevertheless, it is not the Lower Helderberg species that mark the conditions corresponding to the beginning of the Old Red sandstone; but the changes which that fauna suffered during the passage into the Oriskany time are evidences of a general disturbance which resulted in the lifting of large areas of marine surface above the level of the sea.

Taxonomically, we are able to indicate with precision the point in America at which this change from the Silurian to the Devonian systems occurred. However many species may have survived the change, the time of income of the peculiar Oriskany species in Gaspé, New York, and the Appalachians is to be correlated with the Gedennien sandstones and shales of the Rhenish provinces, which hold a sparse but strictly marine fauna, with the corresponding grits of South Devon, with the plant-bearing Foreland sandstones of North Devon, and with the base of the Old Red sandstones of Wales, northern England, and Scotland. This point can be seen in any section in which the fossils are preserved, and furnishes for America one of the most definite boundaries wherever the Oriskany fauna appears.

This transition in the faunas is evident in all the sections in which the Oriskany appears. In this eastern province the termination of the marine faunas occurs at the same place in the faunal succession that was adopted by Murchison as the boundary line between the Silurian and the Old Red sandstone.

Thus in America we have the means of determining the original upper boundary of the Silurian where it passes into the equivalent of the Old Red sandstone, and we are able to locate the Lower Helderberg positively in the Silurian system, in spite of the fact that the typical Lower Helderberg fauna of New York presents close affinities with the earlier marine Devonian faunas of Europe.

Having thus determined for America the taxonomic equivalent for the original boundary between Silurian and Old Red sandstone in Wales, the fixing of the boundary in sections in which the marine faunas continue upward to form a Devonian instead of an Old Red system is a matter of local correlation. The Gaspé and Square Lake limestones of Maine both contain unmistakable evidence of the Lower Helderberg fauna of New York, and both of these limestones occur below the boundary line. The Lower Helderberg is, therefore, proved to belong to the typical Silurian system of the American continent.

The question of the relation of the species of the Lower Helderberg fauna to lower or higher faunas in America does not enter into the problem. Wherever in the sequence the local conditions continued uniform, it is reasonable to suppose that the successive faunas suffered very slight and slow modification with the passage of time.

On the other hand, any grand geologic event which disturbed the relations of land to sea over wide territory would naturally be expressed in more or less complete changes in the composition of the successive faunas.

Nor is it safe to give too much weight to the evidence of apparent similarity of faunas in regions so distant as central Europe and the North American continent. It may be true that the Lower Helderberg fauna resembles the Hercynian fauna in its genera and types of

species more than it does the typical Ludlow. Were this true, as claimed by some European geologists, the actual likeness is no greater than that between the Wenlock and Ludlow faunas, one of which is known to succeed the other.

Looking at all the evidence and giving all respect to the opinion of European geologists, the writer is forced to believe that the evidence of the Maine and New Brunswick faunas confirms the correlations of De Verneuil, Sharp, Bixby, and Hall and Logan as to the place of the boundary line between Silurian and Devonian in North America, and positively shows the Lower Helderberg to lie below that boundary line.[1]

PALEOZOIC FAUNAS ALREADY REPORTED FROM MAINE AND BORDERING REGIONS.

Paleozoic faunas have been recognized in Maine by various authors, and a few localities have furnished lists of species already published. Before reporting the additions recently made, a brief statement of each of the various fossiliferous localities and the lists of species already reported from them will be given. No attempt will be made at present to revise these lists. The faunas from Gaspé and a few other localities are added, in order that the reader may have before him for comparison the facts at present accumulated which bear upon the geologic classification of the Paleozoic rocks of this region.

LOCALITIES IN MAINE.

A paper entitled Notes on the Geology of Maine, prepared by C. H. Hitchcock, State geologist, was read before the Portland Society of Natural History on March 3, 1862, and subsequently published in its proceedings.[2] The paper refers to the collections made by the author in the previous summer (1861) and placed in the hall of the society. Preliminary lists of the fossils are given. Some passages in this report are also found in the Agriculture and Geology of Maine, which, from internal evidence,[3] appears to have been published in 1862, though the date on the title-page is 1861. It is not evident whether the manuscript of the Agriculture and Geology report was handed in at the time of reading the paper above mentioned, or the paper was read first. The report in Agriculture and Geology

[1] Since the above was written a fuller study of the fauna of the Chapman sandstone has been made, and its close correlation established with the fauna of Zone D of Honeyman's upper Arisaig, which was identified by Salter with the Ludlow Tilestone fauna of Wales. The results of these studies were given in a paper read before the Geological Society of America in December, 1899. A paleontologic discussion of the fauna is published in the American Journal of Science for March, 1900. (See the Silurian-Devonian boundary in North America; 1. The Chapman Sandstone fauna: Am. Jour. Sci., 4th series, Vol. IX, pp. 203-213.)—H. S. W., April 3, 1900. (See p. 80.)

[2] Vol. I, Pt. I, pp. 72-85.

[3] The date of publication of the Report on Agriculture and Geology (second series for 1861) is indicated to be as late as 1862 by the date of the secretary's report, which is "January, 1862" (see p. 89).

is the fuller, and it is taken as the standard report of the facts in question.

The fossils, rocks, and minerals of the collections referred to were destroyed by fire in 1866. The lists and identifications of the fossils are hence of special importance, as the originals are not in evidence.

In this Sixth Annual Report of the Board of Agriculture for 1861[1] is included a General Report upon the Geology of Maine, written by C. H. Hitchcock.[2] In the latter part appear lists of fossils from various localities in Maine, which were identified by E. Billings, Emmons, and Sir William (J. W.) Dawson.

Waterville.—The following species of plants were reported by Emmons from the clay slates of Waterville, Maine,[3] referred by Hitchcock to the Lower Silurian formation:

1. Nereograspus jacksoni.
2. Nereograspus loomisi.
3. Nereograspus deweyi.
4. Nereograspus gracilis.
5. Nereograspus lanceolatus.
6. Nereograspus pugnus.
7. Myrianites murchisoni.
8. Myrianites sillimani.

Machiasport.—At Machiasport, at the Point of Maine, Washington County, in dark calcareous slaty rocks underlying red sandstone, are reported the following fossils, determined by Billings, and classified by Hitchcock as Upper Silurian:[4]

1. Modiolopsis.
2. Avicula.
3. Pleurotomaria.

In the midst of certain red sandstones and green shales the following is reported:[5]

1. Avicula.

And in a white limestone in the same series an undeterminable species of shell is reported as completely filling the rocks.[6]

Lubec lead mines.—From similar rocks in the vicinity of the Lubec lead mines, on a little bay north of the productive veins, are:[7]

1. Orthis.
2. Spirifera.
3. Orthoceras.
4. Calymene blumenbachii.

Davis Point.—At Davis Point,[7] and in Perry, running up Little River, are:

1. Lingula.
2. Modiolopsis.

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[1] Sixth Ann. Rept. Secretary Board of Agriculture, 1861, Augusta, 1861 (published 1862).
[2] Op. cit., pp. 146–328.
[3] Op. cit., Augusta, 1861, p. 232.
[4] Op. cit., p. 235.
[5] Op. cit., p. 246.
[6] Op. cit., p. 247.
[7] Op. cit., p. 237.

Pembroke.—At Pembroke[1] fossils are reported "at the extreme south point of the town, near S. Mahar's house" and "in the east part of Pembroke, on Hardon Clark's farm," in "slates, grits, and sandstones of various colors, texture, and degrees of inclination." The locality was discovered by W. B. Rogers, and some of the species were identified by him. The following were determined by E. Billings:

1. Stenopora.
2. Favosites.
3. Petraia.
4. Strophomena.
5. Chonetes.
6. Orthis.
7. Rhynchonella.
8. Spirifera.
9. Retzia.
10. Athyris.
11. Atrypa.
12. Modiolopsis.
13. Avicula.
14. Cyrtodonta.
15. Murchisonia.
16. Pleurotomaria.
17. Platyostoma.
18. Orthoceras.
19. Calymene.
20. Homalonotus.
21. Tentaculites.

The species determined are:

1. Favosites cervicornis.
2. Strophomena rhomboidalis.
3. Chonetes nova-scotica.
4. Rhynchonella wilsoni var.
5. Atrypa reticularis.
6. Orthis musculosa (?)
7. Avicula naviformis.
8. Calymene blumenbachii.
9. Homalonotus dawsoni.

Billings adds: "The rocks of this locality are Upper Silurian and belong to the Lower Helderberg series of the New York survey. They are nearly on the same horizon with those of Square Lake, and also with the upper part of the Arisaig series of Dr. Dawson in Nova Scotia."

The following species are added on the determination of Prof. W. B. Rogers:

10. Discina tenuilamellata.
11. Cornulites flexuosus.
12. Tentaculites distans.
13. Avicula honeymani (?)
14. Beyrichia lata.
15. Spirifer sulcatus.
16. Leptæna rugosa.
17. Orthis elegantula.
18. Modiolopsis ovatus.

Hitchcock mentions[2] "seven other patches of the Lower Helderberg group, mostly limestones," which are identified by containing "the same coral," which is—

1. Favosites gothlandica.

The seven localities are as follows: (1) "Squaw Mountain at the southwest end of Moosehead Lake;" (2) "on an island at the lower end of Ripogenus Lake;" (3) "Horseshoe Pond in No. 5, R. 8;" (4) "in No. 7, R. 7, near the mouth of the Seboois River," and (5) in No. 7, R. 6, east of the Seboois River; (6) Ashland, three localities, one of

[1] Sixth Ann. Rept. Secretary Board of Agriculture, Augusta, 1861, p. 238.

[2] Op. cit., p. 239.

which is "opposite the hotel," and (7) "on the thoroughfare between Portage and Long lakes, and on the west side of Square Lake," the numbers indicating their order as reported by Mr. Packard.

Parlin Pond and Moosehead Lake.—The following fossils from Parlin Pond and Moosehead Lake, in a tough argillaceous sandstone, were identified by Billings.[1]

The genera named are:

1. Strophomena.
2. Chonetes.
3. Orthis.
4. Rhynchonella.
5. Rensselæria.
6. Leptocœlia.
7. Spirifera.
8. Modiolopsis.
9. Cyrtodonta.
10. Avicula.
11. Murchisonia.
12. Platyostoma.
13. Orthoceras.

The species are as follows:

1. Strophomena magnifica (or closely allied).
2. Orthis musculosa.
3. Rhynchonella oblata (or closely allied).
4. Rensselæria ovoides.
5. Leptocœlia flabellites.
6. Spirifera arrecta (or closely allied).
7. Spirifera pyxidata (or closely allied.)[2]

Hitchcock reports large collections of the fossils of the same sandstone from Lake Telos, Webster Lake, and other localities.

On the map accompanying his report Hitchcock has indicated a patch of the Oriskany running obliquely from below Parlin Pond to north of the Aroostook River and the more southerly bend of the Machias River, on No. 10, R. 7.

The Parlin Pond fauna has the following species identified in later publications,[3] on the authority of C. H. Hitchcock:

8. Platyostoma ventricosa Con.
9. Streptorhynchus radiata.
10. Fucoides cauda-galli.
11. Dalmanites epicrates.
12. Leptodomus mainensis Bill.

Seboois River to Presque Isle.—From sundry rocks (sandstones and slates) from other localities in northern Maine, "on the Seboois River," thence to "Aroostook River near Presque Isle," "near Ashland," about the "Eagle Lakes," of which the exact locality is not given, the following species were obtained and identified by Billings:[4]

1. Strophomena rhomboidalis.
2. Rensselæria ovides.
3. Platyostoma.
4. Dalmanites n. sp.

Among the fossils from the sandstone at Webster Lake was identified:

1. Dalmanites sp.[5]

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[1] Sixth Ann. Rept. Secretary Board of Agriculture, Augusta, 1861, p. 244.
[2] This same list is repeated in the report for 1862, p. 286.
[3] See Hitchcock, Am. Assoc. Adv. Sci., 1885 and 1873.
[4] Sixth Ann. Rept. Secretary Board of Agriculture, p. 245
[5] Op. cit., 224.

Perry.—The red sandstones of Perry and vicinity[1] contain a rich flora, which has been described more fully elsewhere, but in the present report a list of eleven species is given on the authority of Dawson.[2]

1. Sternbergia = ? Dadoxylon onangondianum Daw.
2. Aporoxylon sp.
3. Lepidodendron gaspianum Daw.
4. Lepidostrobus richardsoni Daw.
5. Lepidostrobus n. sp.
6. Megaphyton sp.
7. Psilophyton princeps Daw.
8. Leptophlœum rhombicum Daw.[3]
9. Cyclopteris jacksoni Daw.
10. Cyclopteris browniana Daw.[4]
11. Sphenopteris hitchcocki Daw.[5]

The age of this flora is determined as Devonian by the author of the species. The fossil plants were from layers of gray sandstone embedded in the red rocks, which is separated unconformably from lower "Silurian" rocks. The "bedded trap" is said to "spread over the Silurian rocks just as alluvium is spread over the solid rocks" in an exposure southeast of Perry.

Square Lake.—The fossils of the Square Lake fauna, as then identified by Billings, are as follows:[6]

1. Favosites gothlandica.
2. Zaphrentis n. s.
3. Crinoids, 3 or 4 species.
4. Strophomena, new species like S. punctulifera.
5. Strophomena rhomboidalis (S. rugosa Hall).
6. Strophomena, a new species.
7. Rhynchonella wilsoni (var.).
8. Rhynchonella n. sp.
9. Rhynchonella n. sp., like R. acutiplicata.
10. Spirifera perlamellosa.
11. Atrypa reticularis.
12. Athyris bella (Navista belta Hall) [sic].
13. Platyostoma subangulata.
14. Proetus n. sp.
15. Bronteus n. sp.

Other rocks are mentioned by Hitchcock as probably of the same age, but no fossils are named, and hence decisive evidence is lacking. The presence of the Lower Helderberg rocks at the base of Squaw Mountain and at Ripogenus Falls is given on the authority of Mr. Hodge, an assistant of Dr. Jackson.[7]

The Oriskany fauna was recognized by Jackson and W. B. Rogers in several localities previous to Hitchcock's report, but no careful determination of the fossils was made by them.

The fossils of the Square Lake limestone were finally described by Billings in the Proceedings of the Portland Society in 1869.[8] The

[1] Sixth Ann. Rept. Secretary Board of Agriculture, p. 247.

[2] Op. cit., p. 248.

[3] Op. cit., p. 249, figs. 3 and 4.

[4] Op. cit., p. 250, fig. 5.

[5] Op. cit., p. 251, fig. 6.

[6] Op. cit., p. 240.

[7] Op. cit., pp. 378–379.

[8] Descriptions of some new species of fossils, with remarks on others already known, from the Silurian and Devonian rocks of Maine: Proc. Portland Soc. Nat. Hist., Vol. I, Pt. II, pp. 104–125, and plate with 28 woodcut figures of fossils. Portland, 1869.

date of the article is "Montreal, January 12, 1863." The catalogue of the fossils from Square Lake, described by Billings, is as follows:[1]

1. Favosites gothlandica Lam.
2. Zaphrentis cf. Z. prolifica.
3. Diphyphyllum.
4. Crinoid, with moniliform column.
5. Crinoid, with smooth, round column.
6. Fenestella.
7. Incrusting Bryozoan on Orthoceras.
8. Strophomena rhomboidalis Wahlenberg.
9. Strophomena punctulifera Con.
10. Strophomena indenta Con.
11. Strophomena perplana Con.
12. Orthis cf. O. discus Hall.
13. Orthis sp. "a larger species" or nearly the same form.
14. Streptorhynchus?
15. Rhynchonella mainensis n. sp.[2]
16. Rhynchonella nucleolata Hall.
17. Rhynchonella aspasia n. sp.[3]
18. Rhynchonella cf. bialveata Hall.
19. Rensselæria portlandica n. sp.[4]
20. Eatonia medialis Hall.
21. Leptocœlia n. sp.
22. Retzia maria n. sp.[5]
23. Retzia hippolyte n. sp.[6]
24. Retzia dubia n. sp.[7]
25. Retzia electra n. sp.[8]
26. Atrypa reticularis Linn.
27. Athyris blancha n. sp.[9]
28. Athyris harpalyce n. sp.[10]
29. Spirifera macropleura Con.
30. Spirifera raricosta Con., S. Hesione? Bill.[11]
31. Platyceras } both allied to P. subangulata.
32. Platyceras }
33. Loxonema fitchi? Hall.
34. Orthoceras rigidum Hall.
35. Dalmanites epicrates n. sp.
36. Phacops trajanus n. sp.[12]
37. Proetus macrobius n. sp.[13]
38. Proetus junius n. sp.[14]
39. Bronteus pompilius n. sp.[15]
40. Lichas. ?[16]

Billings observes[17] that the aspect of the collection is that of the Lower Helderberg, but there are many new species, "and as it is not quite clear that this fauna can be exactly paralleled with the Lower Helderberg (although it must certainly be very nearly related) it is best to call it Upper Silurian for the present."

Species No. 30 of the above list is the same as that referred to *Spirifer perlamellosa* in the Maine report (see p. 31, No. 10), and the author proposed the name *S. hesione* for it, but refers it provisionally to *S. raricosta* Con. *Athyris blancha*, No. 27 of this list, is cited as *A. bella* in the Hitchcock report of 1861 (see p. 31, No. 12).

Under the name *Strophomena punctulifera* Con., Billings includes the forms figured as *S. punctulifera*, *S. headleyana*, and *S. cavumbona*. Under the name *Strophomena perplana* Con., Billings intends to include *S. pluristriata* Con., *S. planulata*, *S. crenistria*, and *S. fragilis* Hall; and under the genus Retzia King are included Trematospira and Rhynchospira.

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[1] Proc. Portland Soc. Nat. Hist., Vol. I, Pt. II, pp. 104–105.
[2] Op. cit., p. 110, fig. 4.
[3] Op. cit., p. 111.
[4] Op. cit., p. 115, fig. 12.
[5] Op. cit., p. 112, fig. 8.
[6] Op. cit., p. 112, fig. 9.
[7] Op. cit., p. 113, fig. 10.
[8] Op. cit., p. 114, fig. 11.
[9] Op. cit., p. 115, fig. 13.
[10] Op. cit., p. 116, fig. 14.
[11] Op. cit., p. 117, fig. 17.
[12] Op. cit., p. 124, fig. 26.
[13] Op. cit., p. 123, fig. 24.
[14] Op. cit., p. 122, fig. 25.
[15] Op. cit., p. 123, fig. 25.
[16] Op. cit., p. 125, fig. 28
[17] Op. cit., p. 105.

In a still later report, by Bailey and McInnes,[1] the following additional species of this fauna are reported:

1. Pholidops ovata? Hall.
2. Orthis eminens? Hall. (This may be No. 13 of Billings's list.)
3. Orthis strophomenoides Hall.
4. Streptorhynchus perplanum? Con. (Probably No. 14 of Billings's list.)
5. Spirifera perlamellosa Hall. (Cf. No. 30 of Billings's list; this is the species cited in the preliminary list given by Hitchcock in 1861.)
6. Spirifera modesta? Hall.
7. Spirifera sp.?
8. Meristella lævis Van.
9. Retzia formosa Hall sp.
10. Rhynchonella allied to R. aspasia B. and R. altiplicata Hall.
11. Pterinea sp.
12. Platyceras ventricosum Con. (This genus was reported by Billings under two numbers, Nos. 31 and 32.)
13. Platyceras tenuiliratum Hall.
14. Platyceras dilatatum Hall.
15. Platyceras retrorsum Hall.
16. Platyceras curvirostrum Hall.
17. Proetus n. sp.[2]
18. Lichas billingsi n. sp.[2]
19. Leperditia sp.

Billings described, in the former report, several species from other localities and gave lists of the following faunas:

Masardis, Aroostook County.[3]—The Masardis fauna is as follows:

1. Crinoids.
2. Orthis n. sp.
3. Strophomena rhomboidalis.
4. Spirifera nympha n. sp.[4]
5. Atrypa reticularis.
6. Cheirurus tarquinius n. sp.[5]

The author considered this fauna to be equivalent to that of Square Lake. No. 6, *Cheirurus tarquinius*, is reported as being found also in the fauna of Port Daniel, Bay of Chaleur.

Telos Lake.—From Telos Lake the following species are reported by Billings:[6]

1. Crinoid, arms of a large.
2. Chonetes?
3. Rhynchonella or Retzia.
4. Rensselæria ovalis Hall, or a closely allied species.
5. Leptodomus mainensis n. sp.[7]
6. Platyostoma ventricosa? Con.
7. Orthoceras cf. O. rigidum, but more coarsely striated.
8. Dalmanites sp.
9. Avicula or Pterinea.

These are interpreted as "most probably from the base of the Devonian near the Oriskany sandstone."[6]

From the west end of Telos Lake the following are reported:

1. Strophomena rhomboidalis.
2. Streptorhynchus radiata Van.
3. Rensselæria ovalis Hall.
4. Spirifera sp.

This fauna is referred to the same age as the last mentioned.

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[1] Report on explorations and surveys in portions of northern New Brunswick, and adjacent areas in Quebec, and in Maine, United States, by L. W. Bailey and Wm. McInnes: Ann. Rept. Geol. Nat. Hist. Survey Canada, 1887, Vol. III, Pt. M, pp. 1m–52m, and map No. 290.

[2] Op. cit., p. 41m.

[3] Proc. Portland Soc. Nat. Hist., Vol. I, Pt. II, p. 106.

[4] Op. cit., p. 116, fig. 15.

[5] Op. cit., p. 121, fig. 22.

[6] Op. cit., p. 106.

[7] Op. cit., p. 118, fig. 19.

COBSCOOK BAY SERIES.

Professor Shaler[1] has described an interesting series of Silurian deposits on the extreme southeastern coast of Maine, which contain faunas similar to those of the Ashland and Sheridan series of Aroostook County. The deposits resemble these series also in their association with detrital ash beds, lavas, and dikes, indicating disturbances of igneous origin during the Eosilurian period. Four distinct fossil-bearing horizons with their faunas are reported, as follows:

Orange or Whiting Bay.—On the west side of Orange or Whiting Bay, about half a mile south of Balls Mills, in a very dense, much-jointed, siliceous limestone is contained the following fauna, which is correlated by the author with the Lower Helderberg;

1. Orthoceras perstriatum.
2. Orthoceras tenui-annulatum.
3. Holopea antiqua var.
4. Platystoma depressum.
5. Platyceras lamellosum?
6. Platyceras platystomum var.
7. Loxonema allied to L. fitchii.
8. Anatina sinuata?
9. Avicula allied to A. manticula.
10. Avicula allied to A. securiformis.
11. Avicula allied to A. communis.
12. Megambonia allied to M. lata.
13. Megambonia allied to M. ovata.
14. Spirifer modestus?
15. Spirifer perlamelosus.
16. Spirifer cyclopterus?
17. Spirifer octocostatus.
18. Rhynchonella mutabilis.
19. Rhynchonella abrupta.
20. Rhynchonella vellicata var.
21. Rhynchonella formosa.
22. Rhychonella æquivalis var.
23. Rensselæria allied to R. ovalis (doubful).
24. Leptocœlia allied to L. fimbriata.
25. Leptocœlia allied to L. concava.
26. Atrypa reticularis (extremely abundant).
27. Orthis pedunculosa var.
28. Orthis planoconvexa var.
29. Strophodonta planulata var.
30. Strophodonta beckii var.
31. Trematospira allied to T. deweyi.

Dents Point.—At the head of Leightons Cove, about 2 miles to the northwest of Dents Point, in shales, generally thin bedded and containing but little lime, the following, which represent the Clinton and Niagara fauna in New York, are reported:

1. Dalmanites limulurus. Clinton.
2. Beyrichia symmetrica. Niagara.
3. Orthoceras imbricatum.
4. Orthis allied to O. elegantula. } As usual, these two forms blend together.
5. Orthis allied to O. hybrida. } Niagara.
6. Atrypa cuneata var. Niagara.
7. Chonetes allied to C. cornuta, but much larger and with finer ridges. Clinton.
8. Orbicula squamiformis var. Niagara.
9. Lingula oblata. Clinton.
10. Avicula allied to A. textilis. Lower Helderberg.
11. Avicula emacerata. Niagara.
12. Avicula rhomboidea. Clinton.
13. Modiolopsis sublatus. Niagara.

[1] Preliminary report on the geology of the Cobscook Bay district, Maine: Am. Jour. Sci., 3d series, Vol. XXXII, July, 1886, pp. 35-60.

14. Modiolopsis ovatus var. Clinton.
15. Orthonota curta var. Clinton.
16. Cyclonema ventricosa. Clinton.
17. Murchisonia subulata.

Dennysville.—About 1 mile north of Dennysville the following are reported, and referred to the horizon of the Lockport ("Niagara") limestone:

1. Pleurotomaria percarinata var. Trenton.
2. Atrypa nitida var. Niagara.
3. Atrypa aprinis var. Niagara.
4. Spirifer crispus. } Not distinctly separable. Niagara.
5. Spirifer bilobus. }
6. Syringopora multicaulus? Niagara.
7. Heliolites spinipora. Niagara.

Moose Island.—In black and dark-gray shales and slates, on the western shore of Moose Island, from north of Shackford Point to near Eastport, the following faunas, probably belonging to the horizon of the Ohio shale (Devonian), are reported:

1. Modiomorpha allied to M. subulata.
2. Modiomorpha sp. undetermined.
3. Murchisonia desiderata?
4. Beyrichia, species not determined.
5. Lingula, a species not determined.
6. Discina, two species.

NORTH HAVEN SERIES OF PENOBSCOT BAY.

A characteristic Eosilurian fauna has been reported by Messrs. W. W. Dodge and Charles E. Beecher from the island of North Haven.[1] The rocks in which the fossils occur are described as dark bluish-gray, indurated shales, slightly calcareous at places, sometimes with calcareous nodules; red shale with nodules of white limestone; conglomerate sandstones, with dikes, porphyrite, and ash beds associated. The list of species was prepared by C. E. Beecher, who described the majority of the specimens as "too fragmentary and poorly preserved for accurate description or determination." The list given is as follows, the letters indicating separate localities, which are indicated on a map in the original article:[2]

1. Monograptus clintonensis Hall, g.
2. Cœnostroma sp., c.
3. Streptelasma calyculum Hall, g, c.
4. Chonophyllum niagarense Hall, d.
5. Favosites venustus Hall, c.
6. Favosites niagarensis Hall, c.

[1] On the occurrence of Upper Silurian strata near Penobscot Bay, Maine, by William W. Dodge and Charles E. Beecher: Am. Jour. Sci., 3d series, Vol. XLIII, 1892, pp. 412–418.

[2] The letters indicate the successive strata, described by the authors on pages 414 and 415 of the article cited, as follows:

	Feet.
i and j. Sundry argillaceous and calcareous beds above the red shale	175
h. Red shale, J7 and L7 of the author's map	42
g. Dark indurated shale, J and L8–13 of the author's map	203
f. Light-colored porphyry, J14 and L14 of the author's map	3
e. Concealed	75
d. Brown impure limestone, J17, L17, and probably O of the author's map	21
c. Conglomerate, L22–19, and coarse calcareous sandstone, J18 of the author's map	16
b. Concealed	59
a. Conglomerate, J19 of the author's map	12
Total	606

7. Favosites favosus Hall, c.
8. Cladopora sp., d.
9. Cœnites ramulosus Hall, d.
10. Monticulipora sp., i.
11. Halysites catenulatus Linné, c.
12. Heliolites spinoporus Hall, c.
13. Crinoid fragments, i, j, g.
14. Cornulites sp., j.
15. Tentaculites sp., j.
16. Encrinurus punctatus Wahl., g, d.
17. Calymene niagarensis Hall, i.
18. Dalmanites limulurus Green, i, g.
19. Ceraurus niagarensis Hall, i.
20. Illænus ioxus Hall, g.
21. Prœtus stokesi Hall, i.
22. Beyrichia, 2 species, i.
23. Leperditia sp., i.
24. Fenestella sp., i. (In limestone nodule.)
25. Stictopora sp., i.
26. Lingula lamellosa Hall, g.
27. Schizocrania sp., i.
28. Orthis elegantula Dal., i, j, g.
29. Orthis hybrida Sow., i.
30. Orthis, 2 species, g, d.
31. Leptæna transversalis Wahl., g, d.
32. Leptæna (cf.) sericea Sow., i, j.
33. Strophomena rhomboidalis Wilc., g.
34. Stropheodonta profunda Hall, j.
35. Streptorhynchus subplanum Con., i.
36. Chonetes cornutus Hall, i.
37. Pentamerus occidentalis Hall, c.
38. Meristina nitida Hall, i.
39. Meristina sp., i.
40. Nucleospira pisum Hall, d.
41. Cœlospira disparilis Hall, g.
42. Spirifer crispus His., i, j, d.
43. Spirifer sulcatus His., i.
44. Spirifer radiatus Sow., g.
45. Cyrtina pyramidalis Hall, i.
46. Atrypa reticularis Linné, i, j, g.
47. Atrypa nodostriata Hall, d.
48. Rhynchonella neglecta Hall, i, j.
49. Rhynchonella obtusiplicata Hall, i.
50. Rhynchonella sp., i.
51. Rhynchonella (Wilsonia) sp., i, j.
52. Nucula sp., i.
53. Tellinomya sp., j.
54. Avicula demissa Con., i.
55. ?Avicula subplana Hall, g.
56. Avicula sp., i.
57. Cypricardinia sp., d.
58. Platyostoma niagarense Hall, g.
59. Loxonema sp., i, g.
60. Pleurotomaria sp., i, g.
61. Bellerophon sp., i, g.
62. Cyrtolites sp., g.
63. Murchisonia sp., g.
64. Hyolithes sp., j.
65. Orthoceras annulatum Sow., i, g.
66. Orthoceras subcancellatum Hall, g.
67. Orthoceras virgulatum Hall, g.
68. Orthoceras (annulated), 2 species, g.
69. Gomphoceras sp., g.
70. Cytoceras subcancellatum Hall, g.

In a later paper[1] this list is supplemented by the addition of the following species reported by Mr. Beecher, viz:

71. Cyathophyllum sp.
72. Syringopora sp.
73. Ichthyocrinus lævis.
74. Eucalyptocrinus cœlatus.
75. Homalonatus delphinacephalus Gr.
76. Proetus sp.
77. Oncoceras sp.
78. Cœnostroma sp.

Adding the second species recorded under the numbers 22, 30, and 68, and deducting 13 as not a recognized species, the total reaches 80 species for this list.

Concerning the correlation of this fauna the author says that, "It seems justifiable to consider the fossiliferous rock at North Haven as representing a faunal equivalent to the Clinton and Niagara, with a decidedly strong Niagara facies. Therefore, the broader term Niagara will more correctly express the chronological relations of these strata."[2]

[1] The Geology of the Fox Islands, Maine; a Contribution to the Study of Old Volcanoes, by George Otis Smith (published by the author, Skowhegan, Maine, 1896), pp. 22-23.

[2] Am. Jour. Sci., 3d series, Vol. XLIII, p. 417.

LOCALITIES IN CANADA.

Campbell River, Victoria, New Brunswick.—In the Annual Report for 1886,[1] Bailey and McInnes, of the Canadian survey, report a small area of rocks with an Oriskany fauna about 35 miles east and a few miles north of Grand Falls, on the St. Johns River. The rocks are "soft, dark blue, calcareous slates, and soft, dark gray, rusty buff weathering sandstones," and are reported as surrounded by pre-Cambrian and Cambrian rock. The following fossils are identified by Dr. Ami[2]:

1. Carbonized stem of plant.
2. Polypora (?)
3. Strophomena (Strophodonta) magnifica Hall.
4. Strophomena (Strophodonta) varistriata (?) Conrad.
5. Strophomena rhomboidalis Wilc.
6. Orthis hipparionyx Van.
7. Orthis (cf. O. oblata (H.)
8. Leptocœlia flabellites Con.
9. Eatonia (?)
10. Spirifera arrecta Hall.
11. Spirifera (cf. S. submucronata and S. cycloptera).
12. ? Pterinea textilis H.
13. Pterinea, or Megambonia.
14. ? Calymene.

St. Helens Island (near Montreal), Canada.—Mr. William Deeks, in the Canadian Record of Science,[3] has made a careful review of all the material accumulated at McGill College, and publishes the following 'ist of species known to occur in the limestones of St. Helens Island:

1. Crinoid stems.
2. Stenopora.
3. Chætetes abruptus.
4. Callopora incrassata.
5. Favosites helderbergiæ.
6. Favosites sp. ?
7. Zaphrentis corticata.
8. Zaphrentis roemeri.
9. Zaphrentis sp. ?
10. Heliolites.
11. Fenestella cf. perangulata.
12. Ptilodictya acuta.
13. Atrypa reticularis.
14. Chonetes sp. ?
15. Leptæna sp. ?
16. Lingula perlata.
17. Orthis deformis.
18. Orthis discus.
19. Orthis eminens.
20. Orthis hipparionyx.
21. Orthis oblata.
22. Orthis tubulostriata.
23. Pentamerus galeatus.
24. Pentamerus pseudogaleatus.
25. Pentamerus verneuilli.
26. Rhynchonella æquivalvis.
27. Rhynchonella formosa.
28. Rhynchonella mutabilis.
29. Rhynchonella, cf. mutabilis.
30. Rhynchonella nucleolata.
31. Rhynchonella vellicata.
32. Rhynchonella ventricosa.
33. Spirifer cf. S. arenosa.
34. Spirifer concinnus.

[1] Geol. Nat. Hist. Survey Canada, Report on Explorations in Portions of the Counties of Victoria, Northumberland, and Restigouche, New Brunswick, to accompany quarter-sheet map 2 N. W., by L. W. Bailey and W. McInnes, pp. 1n–19n, Montreal, 1887.

[2] Op. cit., p. 8n.

[3] The Lower Helderberg formation of St. Helens Island: Canadian Rec. Sci., Vol. IV, No. 2, pp. 104-109, Montreal, 1890.

35. Spirifer cyclopterus.
36. Stricklandinia gaspensis.
37. Streptorhynchus radiata.
38. Strophodonta profunda.
39. Strophodonta punctulifera.
40. Strophodonta varistriata.
41. Strophomena rhomboidalis.
42. Avicula sp. ?
43. Platyostoma depressa.
44. Tentaculites helena (in loose fragments).

The author states that the following, "from their abundance, may be called the most characteristic fossils of the deposit: "*Atrypa reticularis*, *Pentamerus pseudogaleatus*, *Rhynchonella formosa*, *Rhynchonella nucleolata*, *Spirifer concinnus*, *Spirifer cyclopterus*, *Strophodonta varistriata*, and *Strophodonta punctulifera*."[1]

Another list of the same specimens, determined by Dr. Ami, of the Canadian survey, is published in the Annual Report for 1894.[2] Besides numerous fragments of crinoidal columns, the following are found:

1. Favosites cf. F. gothlandicus Lam.
2. Favosites cf. helderbergiæ Hall.
3. Favosites sp. ?
4. Pachypora sp. 2.
5. Zaphrentis sp. 1.
6. Zaphrentis sp. 2.
7. Cyathophylloid coral sp. ?
8. Callopora or Calloporella.
9. Polypora cf. P. perangulata Hall.
10. Fenestella sp. ?
11. Ptilodictya sp. ?
12. Chonetes cf. melonica.
13. Orthis cf. O. Rhipidomella eminens Hall.
14. Orthis (Rhipidomella) oblata Hall.
15. Orthis cf. (Orthostrophia) strophomenoides Hall.
16. Strophonella punctulifera Conrad.
17. Strophonella cavumbona Hall.
18. Strophodonta varistriata Con. "Tendency toward var. *arata*."
19. Strophodonta varistriata Conrad, "var. more arcuate than type."
20. ? Strophodonta becki Hall, or Streptorhynchus woolworthanum Hall.
21. Leptagonia rhomboidalis Wilc.
22. ? cf. Streptorhynchus radiatum Van.
23. Spirifera concinna Hall.
24. Spirifera concinna (large var.)
25. Spirifera cf. S. cumberlandiæ Hall.
26. Spirifera n. sp. ?

26.[a] Spirifera "of the type of S. arenosa Con."

27. Spirifera cycloptera Hall.
28. Spirifera "sp. with from eighteen to twenty costæ on each side of the mesial sinus. General appearance very much like S. pennata (= S. mucronata), not quite so arcuate and the concentric lines of growth are not so strongly lamellose or rugose."

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[1] Canadian Rec. Sci., Vol. IV, No. 2, p. 108.

[2] Preliminary lists of organic remains occurring in various geological formations comprised in the southwest quarter-sheet map of the eastern townships of the Province of Quebec, by Henry M. Ami: Ann. Rept. Geol. Survey Canada, Vol. VII, new series, p. 155J, Ottawa, 1896.

29. Spirifera cf. S. perlamellosa Hall.
30. Atrypa reticularis Linn.
31. Trematospira multistriata Hall, "or closely related species."
32. ? Leiorhynchus sp. ?
33. Rhynchonella abrupta Hall.
34. Rhynchonella cf. R. acutiplicata Hall.
35. Rhynchonella ? æquivalvis Hall, "possibly a *Rensselæria*."
36. Rhynchonella formosa Hall.
37. Rhynchonella nucleolata Hall.
38. Rhynchonella nobilis Hall. Also cf. R. campbellana Hall.
39. Rhynchonella pleiopleura, or multistriata of Hall.
40. Rhynchonella ventricosa Hall.
41. Eatonia sinuata Hall, or a closely related species.
42. Pentamerus galeatus Dalman.
43. Pentamerus pseudogaleatus Hall.
44. Pterinea sp., cf. P. textilis Hall. A small variety.
45. Platyostoma depressum Hall.

GASPÉ SERIES.

The Gaspé limestones and sandstones are described at length in the report of the Geological Survey of Canada.[1] There is at the base a series of limestones, 2,010 feet thick, divided into eight divisions, numbered from the bottom upward 1 to 8. Comformably succeeding the limestones follow 7,036 feet of sandstones, numbered from below upward as 1 to 8 successive formations.

The fossils from this series were described by E. Billings in the report of the Geological Survey of Canada on "Paleozoic Fossils."[2] The following localities and formations furnished the fossils described:

Locality.	Formation.
A. Indian Cove, Gaspé	Gaspé limestone, No. 8.
B. Cape Gaspé	Gaspé limestone, No. 1.
C. Split Rock, Percé	Lower Devonian.
D. Mount Joli, near Percé	Gaspé limestone, No. 8.
E. Between Cape Gaspé and Cape Rosier	Gaspé limestone, No. 1.
F. Grand Grève, Gaspé Bay	Gaspé limestone, No. 8.
G. Cape Bon Ami, Gaspé	Gaspé limestone, No. 5, passage beds.
H. Little Gaspé	Gaspé limestone, No. 8.
I. Percé, Bay of Chaleurs	Lower Devonian.
J. Gaspé	Gaspé sandstone.
K. Gaspé	Limestone.
L. York River, Gaspé	Devonian.
M. Head of the falls of Dartmouth River	Gaspé sandstone.

[1] Geol. Survey Canada, Report of Progress, 1863, pp. 390-404

[2] Paleozoic Fossils, Vol. II, Pt. I. 1. On some of the fossils of the Gaspé series of rocks, Pl. I—IX, figs. 1-31, pp. 1-64, Montreal, 1874.

The species reported and the new species described are given in the following list, with the letters indicating localities as above:

1. Zaphrentis incondita n. sp. . . A.
2. Zaphrentis rugatula n. sp. . . B.
3. Zaphrentis corticata n. sp . . C.
4. Zaphrentis cingulosa n. sp. . D.
5. Phillipsastrea affinis n. sp. . . A.
6. Polypora ? psyche n. sp. . . . A.
7. Dictyonema splendens n. sp. E.
8. Ptilodictya tarda n. sp. . . . . . F.
9. Lingula lucretia n. sp. . . . . . . G.
10. Lingula artemis n. sp. . . . . . . G.
11. Crania bella n. sp . . . . G.
12. Chonetes melonica n. sp. . . . H.
13. Chonetes canadensis n. sp. . I.
14. Chonetes dawsoni n. sp . . . . C. J.
15. Chonetes antiopa n. sp . . . . . C. D.
16. Chonetes laticosta Hall . . . . . A. F. H.
17. Strophomena galatea n. sp. . A.
18. Strophomena magniventra Hall . . . . A.
19. Strophomena inequiradiata n. sp . . . . A.
20. Strophomena varistriata Con E.
21. Strophomena rhomboidalis Wilc . . . . 1, 5, and 8, K.
22. Strophomena irene n. sp. . . . F.
23. Strophomena blainvillei n.sp J.
24. Strophomena tullia n. sp. . . C. D.
25. Strophomena punctulifera Con . . . . E.
26. Strophomena punctulifera var . . . . A. F.
27. Strophomena cf. perplana Con . . . . K.
28. Orthis livia Bill . . . . A.
29. Orthis aurelia n. sp . . . . A.
30. Orthis lucia n. sp . . . . A.
31. Rhynchonella excellens n.sp A.
32. Rhynchonella dryope n. sp. F.
33. Rhynchonella pleiopleura Con . . . . A.
34. Eatonia peculiaris Con . . . . . A.
35. Pentamerus galeatus Dal. . . . E.
36. Rensselæria ovoides Eaton A. I. C. J.
37. Leptocœlia flabellites Con . . . . Gaspé No. 8 K. J. I.
38. Spirifera gaspensis n. sp . . . . J. C.
39. Spirifera superba n. sp . . . . . A.
40. Spirifera raricosta Con. . . . . . F.
41. Spirifera cycloptera Hall . . . F. A. C.
42. Cyrtina affinis n. sp. . . . . F.
43. Sanguinolites tethys n. sp. . . F.
44. Goniophora mediocris n. sp. A.
45. Grammysia canadensis n. sp J.
46. Modiomorpha inornata n. sp L.
47. Mytilarca canadensis n. sp. No. 8, K.
48. Mytilarca nitida n. sp. . . . . . A.
49. Leptodomus canadensis n.sp A.
50. Anodontopsis ventricosa n.sp A.
51. Cypricardinia distincta n. sp A.
52. Modiolopsis varia n. sp. . . . . E.
53. Murchisonia hebe n. sp . . . . A.
54. Murchisonia egregia n. sp . . M.
55. Pleurotomaria princessa n.sp E.
56. Platyostoma affinis n. sp. (cf. P. ventricosa Con) . . . . A.
57. Pleurotomaria voltumna n.sp . . . . F.
58. Pleurotomaria delia n. sp. . . F.
59. Pleurotomaria lydia n. sp . . A.
60. Bellerophon plenus n. sp. . . A.
61. Proetus phocion n. sp. . . . . . A.

Arisaig, Nova Scotia.—The Arisaig section was correlated with the Silurian of Murchison as early as 1864 by D. Honeyman.[1] Zone D of Honeyman's classification was defined as equivalent to the Upper Ludlow.

[1] On the geology of Arisaig, Nova Scotia, by the Rev. D. Honeyman: Quart. Jour. Geol. Soc. London, Vol. XX, 1864, pp. 333-345.

The following list shows the character of the fauna of the group D:

1. Lituites.
2. Phragmoceras.
3. Ormoceras?
4. ? long, tapering, and recurved.
5. Orthoceras nummulare Sow.
6. Orthoceras, very like O. bullatum Sow.
7. Orthoceras ibex Sow.
8. Orthoceras exornatum Dawson.
9. Orthoceras punctostriatum Hall.
10. Orthoceras, 4 sp.
11. Bellerophon trilobatus Sow.
12. Bellerophon carinatus Sow.
13. Bellerophon striatus D'Orb.
14. Bellerophon expansus Sow.
15. Theca Forbesii Sharpe.
16. Coleoprion ? sp.
17. Murchisonia Arisaigensis Hall.
18. Murchisonia aciculata Hall.
19. Pleurotomaria.
20. Modiolopsis ? rhomboidea Hall.
21. Modiolopsis subnasuta Hall.
22. Clidophorus cuneatus Hall.
23. Clidophorus concentricus Hall.
24. Clidophorus erectus Hall.
25. Clidophorus elongatus Hall.
26. Clidophorus semiradiatus Hall.
27. Clidophorus nuculiformis Hall.
28. Clidophorus subovatus Hall.
29. Avicula Honeymani Hall.
30. Pterinea retroflexa.
31. Orthonota (like many Ludlow species) Salter.
32. Goniophora cymbæformis Sow.
33. Chonetes Nova-Scotica Hall.
34. Chonetes tenuistriata Hall.
35. Orthis, 2 sp.
36. Spirifer subsulcatus Hall.
37. Rhynchonella, 3 sp.
38. Discina rugata Sow.
39. Discina ? lineata.
40. Discina ? tenuilamellata Hall.
41. Crania Acadiensis Hall.
42. Lingula sp.
43. Homalonotus Dawsoni Hall.
44. Homalonotus Knightii König.
45. Dalmania Logani Hall.
46. Phacops Downingiæ Salt.
47. Calymene, different from Blumenbachii Brong.
48. Proetus Stokesii ?
49. Beyrichia pustulosa Hall.
50. Beyrichia equilatera Hall.
51. Beyrichia, 2 sp.
52. Leperditia sinuata Hall.
53. Crinoidea.
54. Tentaculites.
55. Cornulites serpularius.
56. Serpulites n. sp. (in clusters on shell of Orthoceras).
57. Stenopora.
58. Heliopora fragilis var. Acadiensis Hall.

The species in this list followed by the name of Hall were all described by James Hall[1] from this locality.

Mr. Salter examined this fauna, and "unhesitatingly referred it to the Ludlow tilestone." This is the upper member of the Silurian of modern classification, and is called the Downtonian.

Dr. Ami has recently made a study of this section, and identified the fossils in the Canadian survey office coming from the Arisaig section. His identifications are published in the Proceedings and Transactions of the Nova Scotian Institute of Science, Halifax, 2d series, Vol. I, Pt. I, pp. 185–192. A list of 163 species is given, but the association of these species into separate faunas is not made in the list, and they include both Upper and Lower Silurian species. A further study of these sections should throw some light upon the Maine faunas.

[1] Description of new species of fossils from the Silurian rocks of Nova Scotia, by James Hall: Canadian Nat. and Geol., Vol. V, 1860, pp. 144–159.

SOME ADDITIONAL FAUNAS CLOSELY ALLIED TO MAINE PALEOZOIC FAUNAS.

Oriskany of Becraft Mountain, New York.—The following list gives the preliminary determination of species found in the Becraft fauna and reported by J. M. Clarke.[1]

1. Spine of undetermined fish.
2. Spirorbis sp.
3. Autodetus sp. n.
4. Dalmanites sp. n. A.; cf. D. anchiops, D. pleuroptyx.
5. Dalmanites sp. n. A. var.; cf. D. micrurus.
6. Dalmanites sp. n. B.; cf. D. dentatus.
7. Dalmanites sp. n. C.
8. Dalmanites sp. ? D.; cf. D. pleuroptyx.
9. Dalmanites phacoptyx. (Up. Held., Ontario.)
10. Phacops sp. n.; cf. P. logani.
11. Phacops (Acaste) cf. anceps. (Up. Held., Ontario.)
12. Homalonotus sp. (small); cf. H. major.
13. Cordania sp. n.; cf. C. cyclurus.
14. Cyphaspis sp. n.; cf. C. coelebs, C. minuscula.
15. Proetus sp. n. ? A.; cf. P. angustifrons-clarus-Rowi.
16. Proetus sp. n. B.; cf. P. crassimarginatus.
17. Acidaspis tuberculatus.
18. Leperditia sp.
19. Primitia sp.
20. Turrilepas sp.
21. Platyceras tortuosum.
22. Platyceras nodosum.
23. Strophostylus expansus.
24. Diaphorostoma ventricosum.
25. Diaphorostoma sp. n.; cf. D. lineatum.
26. Cyrtolites expansus ?
27. Pleurotomaria sp. n.
28. Bellerophon sp. n. ?
29. Conularia sp. ?
30. Coleolus sp. ?
31. Tentaculites cf. elongatus.
32. Tentaculites sp. n.
33. Actinopteria cf. textilis.
34. Aviculopecten cf. A. scholiarie.
35. Megambonia bellistriata.
36. Megambonia lamellosa.
37. Goniophora sp. n.
38. Cypricardinia cf. lamellosa.
39. Conocardium sp.
40. Lingula sp.
41. Orbiculoidea sp.
42. Crania sp. n.; cf. C. agaricina.
43. Crania sp. n.
44. Pholidops terminalis=P. arenaria.
45. Pholidops sp. n.; cf. P. squamiformis.
46. Orthis perelegans.
47. Orthis cf. oblata.
48. Orthis sp. ?
49. Orthothetes cf. woolworthana.
50. Orthothetes sp. n.; cf. O. lens.
51. Hipparionyx proximus.
52. Leptæna rhomboidalis (not var. ventricosa).
53. Stropheodonta lincklæni.
54. Stropheodonta cf. radiata; cf. S. demissa.
55. Stropheodonta sp. n. A.; cf. Rafinesquina alternata.
56. Stropheodonta sp. n. B.; cf. S. alveata.
57. Leptostrophia magnifica (small).
58. Leptostrophia cf. becki (small and abundant).
59. Leptostrophia perplana (but more convex).
60. Strophonella cf. headleyana.
61. Vitulina?
62. Chonetes sp. n.
63. Chonostrophia sp. n.
64. Anoplia nucleata.
65. Spirifer arrectus; cf. S. cyclopterus.
66. Spirifer arenosus.
67. Spirifer pyxidatus.
68. Spirifer modestus.
69. Spirifer cf. fimbriatus.
70. Cyrtina rostrata.
71. Cyrtina cf. dalmani.
72. Meristella sp. n.; cf. M. oblata.
73. Meristella cf. lævis.
74. Meristella sp. n.
75. Trematospira multistriata.

[1] Notice of a new Lower Oriskany fauna in Columbia County, New York, by C. E. Beecher; with an annotated list of fossils, by J. M. Clarke: Am. Jour. Sci., Nov., 1892, 3d series, Vol. XLIV, p. 411.

76. Coelospira sp. n.; cf. C. camilla and C. concava.
77. Coelospira sp.; cf. C. concava.
78. Leptocœlia flabellites.
79. Leptocœlia acutiplicata.
80. Anastrophia sp. n.
81. Rensselæria ovoides.
82. Rensselæria suessiana?
83. Rensselæria ovalis?
84. Rhynchonella oblata.
85. Rhynchonella barrandii.
86. Rhynchonella cf. speciosa.
87. Rhynchonella sp.
88. Eatonia medialis.
89. Eatonia peculiaris.
90. Centronella sp. n.; cf. C. glans-fagea.
91. Cryptonella sp. n.
92. Fenestella celsipora.
93. Fenestella sp.
94. Hemitrypa cf. columellata.
95. Polypora sp.?
96. Reptaria sp.
97. Hederella sp.
98. Clonopora sp.
99. Fistulipora sp.
100. Zaphrentis cf. rœmeri.
101. Zaphrentis sp.?
102. Romingeria sp.
103. Monticulipora.
104. Trachypora sp.
105. Edriocrinus sacculus.
106. Hindia sp.

Baileys Landing, Perry County, Missouri.—This fauna, referred to the "Lower Helderberg group" (Delthyris Shaly limestone) by Meek and Worthen,[1] is important in the present discussion, as it exhibits the combination of forms in this central area about a thousand miles distant, to the south and west, from the typical New York localities. The fossils come from a limestone. The following list of species is given by Meek and Worthen:

1. Striatopora missouriensis n. sp.
2. Edriocrinus pocilliformis Hall.
3. Orthis hybrida Sowerby? (cf. O. oblata.)
4. Orthis subcarinata Hall.
5. Strophomena (Strophodonta) cavumbona Hall?
6. Merista lævis Van? (sp.).
7. Zygospira subconcava M. & W.
8. Trematospira? imbricata Hall.
9. Cyrtina dalmani Hall (sp.).
10. Spirifer perlamellosus Hall.
11. Platyceras subundatum M. & W.
12. Platyceras spirale Hall.
13. Platyceras (Orthonychia) pyramidatum Hall?
14. Acidaspis hamata Con. (sp.).
15. Dalmanites tridentiferus Shumard.

Clear Creek, Union County, Illinois.—In a cherty limestone.

The following fauna from southern Illinois is described by Meek and Worthen,[2] and referred to the Oriskany group by them. The species named occur in a cherty limestone, and are as follows:

1. Leptæna? nucleata Hall.
2. Rhynchonella speciosa Hall.
3. Eatonia peculiaris Con. (sp.).
4. Leptocoelia flabellites Con. (sp.).
5. Spirifer engelmanni M. & W. (cf. S. arrectus).
6. Spirifer hemicyclus M. & W. (cf. S. varicosus).
7. Rensselæria condoni McChesney (cf. ovalis).
8. Stricklandinia elongata var. curta. =Amphigenia curta M. & W.
9. Strophostylus? concellatus M. & W.
10. Platyceras spirale Hall?

Jonesboro, Union County, Illinois.—Meek and Worthen report the following species from a light yellowish, friable sandstone outcrop-

[1] Geol. Survey Illinois, Vol. III, Geology and Paleontology, Fossils of the Lower Helderberg group (Delthyris Shaly limestone), 1868, pp. 368–392.

[2] Geol. Survey Illinois, Vol. III, Geology and Paleontology, 1868, pp. 393–406.

ping at Jonesboro, in southern Illinois, and refer the fauna to the Corniferous group.[1]

1. Pleurodictyum problematicum Goldf. ?
2. Baryphyllum ?? arenarium M. & W.
3. Zaphrentis (sp. undt.).
4. Orthis sp. (cf. O. musculosa).
5. Strophomena (Strophodonta) sp. ?
6. Strophomena (Strophodonta) sp. ?
7. Productus exanthematus Hall ??
8. Spirifer perextensus M. & W.
9. Spirifer paradoxus Schlot ?? (sp.).
10. Odontocephalus — ?
11. Dalmanites (Odontocephalus) ægeria Hall ? (sp.).

NEW PALEOZOIC FAUNAS FROM AROOSTOOK AND SOMERSET COUNTIES, MAINE.

The new Paleozoic faunas from these counties include the faunas of (1) the Aroostook limestone, (2) the Graptolite shales, (3) the Sheridan sandstone, (4) the Ashland shales, (5) the Ashland limestone, (6) the Square Lake limestone, (7) the Chapman sandstone, (8) the Moose River sandstone, and (9) the Mapleton sandstone.

AROOSTOOK LIMESTONE.

Under the above name are grouped the calcareous shales and slates covering a large part of the eastern township of Aroostook County. Their petrographic and structural characters are described by Dr. Gregory (p. 141, et seq.). The Aroostook River cuts them from Wade Township to its junction with the St. John. They were referred to the Upper Silurian by Hitchcock,[2] and later writers have not succeeded in getting much more definite knowledge of their age.

The few fossils found in them indicate as great age as the Clinton, and comparison with neighboring rocks to the west confirms this general estimate. Cleavage has affected them to such an extent that it has produced real slaty cleavage occasionally, and in most cases has so much disturbed the original structure by cross-cleavage planes as to make the original bedding difficult to discover, except where bands of limestone appear.

The few fossils obtained are fucoids and trails and markings of worms or some other marine animals. Specimens in light-greenish shales at Caribou and Presque Isle resemble the forms figured in the New York reports as *Buthotrephis gracilis* from the Clinton shales. Traces of Acidaspis are also seen, and in calcareous layers in Presque Isle and Mapleton *Bilobites bilobus*, an Orthis close to *O. elegantula*, and *Nucleospira pisiformis* have been discovered.

These all indicate that the formation was as late as Eosilurian, and not as early as Ordovician (Lower Silurian). If this interpretation

[1] Geol. Survey Illinois, Vol. III, Geology and Paleontology, pp. 407–418.
[2] Sixth Ann. Rept. Secretary Board of Agriculture, Maine, 1861.

be adopted, the terrane may be regarded as older than the Sheridan sandstone and Ashland shale and limestone, and as representing the base of the Silurian for this region.

There is little doubt as to its being more recent than the pure, non-calcareous slates, a considerable belt of which cuts across the country in a southwesterly direction west of the Aroostook limestone.

GRAPTOLITE SHALES.

In the northern part of Chapman Township Dr. Gregory discovered, in 1898, a calcareous sandy shale containing graptolites. The section (1099 D)[1] is on the sides of a hill in the western part of Chapman, on W. H. Littlefield's farm, on the west side of the Swanback road, and about three-fourths mile south of the Mapleton line.

The strata present two planes of fissility, as is frequently the case with the shales of all this region. Judging, however, from the plane in which the graptolites lie in the rock, the strike of bedding is about N. 35° E., with a dip of about 60° NW. The other plane of fissility has a strike of about N. 70° W., and dips at an angle of 25° SE. With this interpretation of the position of the strata, 1099 D 5 on the west side of the hill would be the highest stratum; then D 1, which may be a continuation of D 5, and below this D 2 and then D 3. 1099 D 3 is a fine-grained brown-gray sandstone, with nodules or lenticles of argillaceous limestone, which are believed to be the Aroostook limestone. This weathers by leaching to a rottenstone, in which condition no bedding is evident. In D 3 graptolites are rare, but Coleolus is frequent. Above D 3, 150 feet or so, the shales, D 2, are dark gray and little calcareous, or not at all so, and glisten with mica grains on the fractures, the rock splitting along what are believed to be the bedding planes, on which lie the fossil graptolites.

Above D 2 is D 1, more purely arenaceous than D 2, and fine grained. This stratum contains only occasional crinoid stems and fragments of corals or some other calcareous fossil.

On the opposite or west side of the hill, still dipping westward, is D 5, which closely resembles D 1, and which contains crinoid stems and traces of Coleolus. The immediate relation to other rocks is not evident, but about a quarter mile to the north of D 3, on lot 9 of Chapman Township, occurs a limestone striking N. 30° E. and standing nearly vertical. At that exposure the limestone abuts against a sandstone similar to the one farther south, and it is probable that the sandstones are stratigraphically older than the limestone. The fossils of this limestone enable us clearly to identify its age as Eosilurian. The fauna is that of the Ashland limestone.

[1] The numbers here and below refer to the rock exposures, the locations of which are given in Pt. III of this bulletin.

The semislaty structure of the shaly sandstones also is evidence that they are not as late as the Chapman sandstones of the same region, which are not slaty at all, but are nearly flat and undisturbed by the cleavage which has affected all of the older rocks of the region.

Fauna of 1099 D 2 and 3.

1. Monograptus (Graptolithus clintonensis) priodon.
2. Cardiola interrupta.
3. Coleolus tenuicinctum.
4. Coleolus aciculum.
5. Orthoceras cf. virgulatum.

And a few other forms.

The Graptolite shale is believed to be of Silurian age, but the fauna is a remarkable combination. Coleolus is as characteristically Devonian as Monograptus is Silurian. The specimens of Coleolus present the characteristics met with in the typical Mesodevonian forms of New York.

The Cardiola is certainly of the type of *C. interrupta*, which all over Europe is characteristic of the Silurian horizon. The three forms are certainly from the same rock formation.

The facts deserve more exhaustive treatment than can be given in this preliminary report. They confirm the conviction, already reached by the author from the study of the Black shales of the Devonian, that faunas which we are accustomed to call pelagic, and which we find generally in fine-grained, uniform, very thin-bedded, and often calcareous shales, but usually in more or less siliceous shales, are locally of great taxonomic importance for the same geologic basin. Nevertheless, the faunas themselves contain species which have long stratigraphic range, and which can not be relied upon for close determination of chronologic position in the geologic series.

As an illustration, in case we were to find *Coleolus tenuicinctum*, or any form closely allied to it, though it might be called specifically by another name, the containing rock would be referred on such evidence alone to the Devonian. If *Monograptus priodon* or any graptolite of this type of structure were to be found alone, it would certainly be referred to the Silurian system. When the association of the graptolite with a true Cardiola of the *interrupta* type occurs, it is impossible to assign the rocks a position higher than Silurian.

The close resemblance of the specimens of Coleolus to the so-called embryo tubes of *Endoceras proteiforme* of the Ordovician rocks[1] of New York, and to similar forms from the Bohemian Basin figured by Barrand, suggests the explanation that these peculiar fossils, which occur in strata of so widely separated age, were internal shells, comparable to phragmocones, and with a chemical composition which escaped the solvent effects of the deeper waters in which they were probably fossilized.

[1] Pal. New York, Vol. I, pp. 213 et seq., and pls. 45, 46, 47.

SHERIDAN SANDSTONE.

The Sheridan sandstone is described, in its lithologic features, in Part II of this report (p. 132). In its appearance it is a peculiar rock, looking like an ordinary sandstone of various degrees of fineness and in its coarsest state a pebbly conglomerate.

The color is greenish gray to rather dull brown. When closely inspected it is found to be composed of soft and hard rocks, both rounded and angular—quartz and feldspar; jasper, slate, and argillaceous shale, green, red, and black; and fragments of fossils, corals and crinoids, but particularly pieces of brachiopods of size large enough to recognize.

The most conspicuous feature about the rock is the angular pieces of black slate, which at first suggest fragments of carbonaceous matter, but are evidently fragments of the more ancient slates. What is petrographically important about them is that igneous materials also are associated with them, emphasizing their close association in origin with the tuffs and volcanic ash beds with which they are stratigraphically associated.

The evidence is clear, as is brought out in Dr. Gregory's report, that the Sheridan sandstones were formed at a time of, and in a region subjected to, violent volcanic eruptions.

Sheridan Plantation.—The typical exposure (1097 A) of this sandstone and its fauna is found in Sheridan Plantation, south of the river, on the road from Ashland to Presque Isle, a few rods north of the Sheridan southern line.

Fauna of 1097 A.

1. Strophomena rhomboidalis.
2. Orthothetes subplanus.
3. Anoplotheca hemispherica.
4. Leptæna transversalis.
5. Orthis, several species.
6. Stropheodonta sp.
7. ? Atrypa reticularis.
8. ? Platystoma sp.
9. Corals, several species.
10. Spirifer cf. radiatus.

A second exposure (1097 E) is on the right bank of the Aroostook River a short distance below the mouth of Alder Creek. Here the characteristic sandstone is seen with fragments of fossils, but none gathered were perfect enough to make out the species.

Other exposures of the same sandstone were seen, one (1097 F) south of the same road at the Frenchville store and church, and another (1097 H) at Alley's grindstone quarry on the Alley farm, on the right bank of Aroostook River about a mile west of the east line of Sheridan Township. Fragments of fossils were seen in these several exposures, but they were mainly too much broken for identification. At Alley's grindstone quarry an undetermined brachiopod resembling Cyrtia, but with punctate shell, was seen (catalogued as No. 504), which is also present in the shales at Ashland (1098 C 3).

New Sweden Township.—In New Sweden Township an outcrop (1096 A) was seen on the middle road from Woodland to New Sweden, on the west side of the road near the township line. This rock furnished some characteristic species, as follows:

Fauna of 1096 A.

1. Anoplotheca hemispherica.
2. Leptæna transversalis.
3. Pentamerus cf. oblongus.
4. Pleurotomaria sp.
5. Cf. Streptelasma calcula.
6. Cf. Paleodelasma turbinatum.
7. Cf. Cladopora fibrosa.

Drift bowlders.—Some of the better-preserved fossils were obtained from drift bowlders, catalogued under the station number 1095. As there can be no mistaking the fauna and the sandstone in these bowlders, the faunas will be given.

The following fauna was found in a drift bowlder (1095 B) on the farm of R. Wither at Woodland:

Fauna of 1095 B.

1. Leptæna transversalis.
2. Strophomena rhomboidalis.
3. Orthothetes subplanus.
4. Stropheodonta cf. perplana.
5. Acidaspis tuberculatus.
6. Cf. Trematospira multistriata (young).
7. Spirifer cf. niagarensis (young).
8. Pentamerus cf. oblongus.
9. Orthis, two species.
10. Fragments of undetermined species.

A second bowlder from Woodland (1095 C) contained the following species:

Fauna of 1095 C.

1. Leptæna transversalis.
2. Gastropods, several small species.
3. Bellerophon sp.
4. Favosites cf. niagarensis.
5. Corals, several species.
6. Orthis sp.

The following fauna was found in a drift bowlder (1095 D) at Caribou, Maine:

Fauna of 1095 D.

1. Leptæna transversalis.
2. Strophomena rhomboidalis.
3. Bilobites bilobus.
4. Cf. Trematospira multistriata.
5. Orthothetes sp.
6. Pentamerus sp.
7. Anoplotheca hemispherica.
8. Several undetermined fragments.

In the township of Mars Hill (1296 F), near the north end of Mars Hill, on the west side, in the field at its base, another bowlder was found containing the typical fauna, the petrographic characters also agreeing with the rock at the typical exposures.

Fauna of 1296 F.

1. Strophomena rhomboidalis.
2. Leptæna transversalis.
3. Pentamerus oblongus.
4. Spirifer radiatus.
5. Atrypa cf. obtusiplicata.
6. Atrypa cf. reticularis.
7. Orthothetes sp.
8. Several other brachiopod fragments.
9. A few crinoid segments.

In the above lists the species cited are generally of small size for the species represented. *Leptæna transversalis* is found in almost every case, and in each of the very sparse collections is generally represented by more than one specimen. The species was evidently very common.

The fauna of the Sheridan sandstone presents affinities with both the Clinton and the Niagara of New York. It is believed that the Sheridan sandstone precedes the Ashland limestones, whose fauna is described elsewhere. However, the actual stratigraphic relationship of the limestone to the Sheridan sandstone has not been observed. *Bilobites bilobus* is not recorded from the Clinton. On the other hand, *Anoplotheca hemispherica* is a Clinton species. It represents the upper part of the Anticosti group.

ASHLAND SHALES.

Ashland Village.—In Ashland Village, along the road opposite the hotel, and southward toward Masardis, are several outcrops of limestones, calcareous shales, and sandstones which present stratigraphic relationship to one another, but on account of the shear planes and semislated structure, as well as the intervals unexposed, some doubt must be held regarding the accuracy of the interpretation.

The strike of the various exposures examined is northeasterly (N. 80° E., N. 85° E., N. 30°–50° E.), and the dip northwesterly at angles of 60°, 75°, and 55°, thus giving the impression that the exposures on the north-south road are lower toward the south.

The irregular, blocklike masses of limestone opposite the hotel are met on the southern side by yellowish, weathered shales. There is then an interval of several hundred feet south of 1098 A 1 showing no rock exposures.

On the east side of the road there is a rock cut (1098 A 3), about 400 feet south of the hotel. The rocks in this exposure are calcareous, thin-bedded shales, somewhat nodular and weathering yellowish from iron oxide. Some layers contain nearly pure argillaceous shales, others are calcareous. The calcareous layers are all somewhat arenaceous, showing pebbles of quartz, jaspers, and siliceous slates, mingled with broken calcareous shells, and an approach to the conditions of the Sheridan sandstone.

The fossils are corals, crinoids, and pieces of brachiopods. The better specimens of fossils are from the finer shaly layers next the calcareous layers. This exposure is 1098 A 3, and is the typical Ashland shale.

Fauna of 1098 A 3.

1. Leptæna transversalis.
2. Strophomena rhomboidalis.
3. Orthothetes subplanus.
4. Atrypa reticularis.
5. Orthis flabellites.
6. Stropheodonta corrugata.
7. Calymene niagarensis.
8. Cf. Cyrtia n. sp.
9. Spirifer cf. nympha Billings.
10. Platyceras sp.
11. Corals, undetermined.

Winslow farm.—In the section at Winslow's farm there is the same confusion, due to the complication between the bedding and cleavage planes. This section was examined and reported by Dr. Gregory. It is station 1098 K 1–5, and is in the field east of the road, on Winslow's farm, 1½ miles south of Ashland.

At the western end of the section K 1 is a fine-grained calcareous sandstone, dark gray in color, with occasional mica grains. It weathers to a brown rottenstone. The strike of what appears to be the bedding is N. 60° E.; the dip is 40° to 50° NW.

Passing eastward over the edges, the next exposure (K 2) is still a calcareous sandstone of the same character, with lenticular masses and layers of limestone conglomerate, made up of crinoid and coral fragments and well-worn pebbles of siliceous rock and limestone. The contact between the calcareous, shaly sandstone and the conglomerate rock is sharp. The whole is much broken up by cleavage and fracture planes. The strike and dip are as above.

At the next exposure eastward, 300 feet east of K 2, is K 3, which is a fine-grained gray sandstone, weathering brown, little or not at all calcareous. The bedding of this rock, as indicated by darker strata, has a strike of N. 35° W. and a dip of 10° NE. What were taken for cleavage planes strike N. 45° E., with a dip of 70° NW. This agrees better with the structure of adjacent rocks. Other planes of fracture strike N. 35° W., dipping 20° NE., and strike N. 30° W., standing vertical. No fossils were seen in the terrane. Still farther eastward, 100 feet beyond K 3, an outcrop marked K 4 is seen. This is a sandstone shale with calcareous conglomerates. In these calcareous masses are fragments of shale, siliceous, well-worn pebbles as large as 3 inches in diameter, and fragments of cracked limestone. Beyond this is a large mass (K 5) of the fractured limestone, 100 by 8 by 5 feet. No good fossils were collected, but the fragments are of the same corals, brachiopods, and other forms seen in the Ashland limestone.

The rocks are in appearance much like those in Ashland Village, with the exception that in the latter exposures the conglomerate mass is not so clearly expressed. The fossils in the shale correspond closely to the fauna of Ashland shale already listed.

Fauna of 1098 K 2.

1. Orthothetes subplanus.
2. Strophomena rhomboidalis.
3. Stropheodonta perplana Billings.
4. Orthis cf. elegantula.
5. Spirifer bicostatus.
6. Brachiopods, several undetermined species.
7. Corals, several species.
8. Crinoid stems.

The Ashland shales, the Sheridan sandstone, and the Ashland limestone contain faunas of the Eosilurian, and from the evidence of structure already collected it is difficult to tell their exact relationship to one another. The writer's interpretation, with his present knowledge of the facts, is that the shales are older than the limestones, and that the Sheridan sandstones are of the same age as the shales.

The disturbances which occurred in the ash beds and the associated Sheridan sandstone may also account for the fragmental condition of the Ashland limestone. If so, it is necessary to consider the limestone as already consolidated. This might have been the case and still the difference in age might be very slight, geologically speaking, for the consolidation of a coral reef deposit, though it might take centuries, does not require long geologic periods.

In case the volcanic disturbances took place during the general Niagara time, the faunas and the condition of the several kinds of rock and their irregular relations may be rationally accounted for. In the faunas themselves there is clear evidence for the separation of the Square Lake fauna from those now under consideration. The Square Lake fauna is clearly equivalent to the Lower Helderberg of the New York series, and nearly to the "Delthyris Shaly limestone" part of it. The Ashland limestone, Ashland shale, and Sheridan sandstone faunas are all older and may be correlated more closely with the Niagara of the New York series.

It is to be observed, however, that the Sheridan sandstone faunas combine species of typical Niagara or even Clinton stages of New York with other species not found in that region below the Lower Helderberg. We may cite, for instance, *Cypricardinia lamellosa* and *Phacops logani*. Not only these, but closely allied species are found in the two faunas.

In New Sweden, on the Olivenbaum farm (1096 H), a fine-grained shale, calcareous, but with enough siliceous grains to preserve the consistency of the rock after the lime is leached out, contains numerous crinoid stems, and among them are recognized plates of *Caryocrinus ornatus*, which determine the age to be that of the Clinton or Niagara of New York. For the present these may be referred to the Ashland shales.

ASHLAND LIMESTONE.

The limestone at Ashland was referred to by Hitchcock in his report for 1861,[1] as follows:

The next belt of this limestone [referring to seven patches of the Lower Helderberg group] noticed is in Ashland, where it has been burned for lime. This bed is largely fossiliferous, containing the *Favosites gothlandica*, a *Zaphrentis*, *Strophomena rhomboidalis*, etc. It occurs in three places in this town, viz: In the center, opposite the hotel; a mile south, and a mile north of the village. The rock at the southern locality dips 70° westerly; but the comparison of all the exposures of the limestone here show that it forms the base of an anticlinal axis; consequently the rocks on the east and west sides of it are newer, that is, of Devonian age.

Billings, in his paper in the Proceedings of the Portland Society,[2] does not describe this particular fauna. The fauna from Masardis is, however, listed as follows:

Fossils from Masardis.—The fossils from Masardis are Crinoids, a new species of *Orthis*, *Strophomena rhomboidalis*, ***Spirifera nympha***, *Atrypa reticularis*, and *Cheirurus tarquinius*. This rock is also Upper Silurian and of the same age as that at Square Lake. One of the species, *C. tarquinius*, is quite common at Port Daniel, on the Bay of Chaleur, where it is associated with *Bronteus pompilius*, so characteristic of the Square Lake limestone.

The typical locality for the Ashland limestone is a ledge opposite the Ashland Hotel, in Ashland Village. The limestone is mainly a pure gray limestone, but much fractured, as if broken in process of faulting. This fragmental, brecciated condition is common to it wherever seen, and as far distant as the Dudley farm in Castle Hill (1415 L) the limestone, though in apparently comformable beds in the series of shales and slates, presents the same brecciated appearance.

The study of the fossils has led the writer to associate the following outcrops as all belonging to the same general horizon, and if not belonging to a continuous calcareous set of strata the probabilities are in favor of regarding them as more or less local calcareous masses in a series of calcareous shales of approximately the same geologic age.

Ashland, 1098 A 1. Ledge opposite the hotel in Ashland Village.
1098 F 1. On Gilman's farm, three-fourths mile south of Ashland, along the Masardis road.
1098 K 4. In field east of road, on Winslow farm, 1½ miles south of Ashland Village.
Castle Hill, 1415 L. On the L. W. Dudley farm, 2½ miles west of Mapleton Village.
Chapman, 1099 D 6. On the W. H. Littlefield farm, west of road along west side of Chapman (called "Swanback" road), three-fourths mile south of Mapleton line.

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[1] Agriculture and Geology of Maine, second series (= Sixth Ann. Rept.), Augusta, Me., 1862, p. 240.
[2] Proc. Portland Soc. Nat. Hist., Vol. I, Pt. II, pp. 104-126.

Ashland Village.—At Ashland Village the following species were found:

Fauna of 1098 A 1.

1. Strophomena rhomboidalis.
2. Anoplotheca hemispherica.
3. Leptæna transversalis.
4. Orthothetes subplanus.
5. Atrypina imbricata.
6. Spirifer nympha Billings (cf. radiatus).
7. Stropheodonta perplana Billings.
8. Atrypa cf. neglecta.
9. Atrypa cf. nitida.
10. Atrypa cf. intermedia.
11. Orthis sp.
12. Meristella sp.
13. Pentamerus liqueatum.
14. Pentamerus cf. galeatus.
15. Spirifer cf. Jaschei (perlamellosa var.)
16. Cf. Trematospira sp.
17. Rhynchonella cf. stricklandi.
18. Rhynchonella cf. nympha, oblata.
19. Rhynchonella, several small species.
20. Mytilarca canadensis.
21. Cypricardinia lamellosa.
22. Cypricardinia cf. depressa.
23. Cypricardinia cf. crassa.
24. Strophostylus elegans.
25. Platyceras cf. retrorsum.
26. Phacops logani.
27. Dalmania cf. anchiops.
28. Bronteus cf. pompileus.
29. Favosites niagarensis.
30. Cf. Polydelasma turbinatum.
31. Cf. Diphophyllum cæspitosum.
32. Corals, several undetermined.

Gilman farm, Ashland.—At Gilman's farm, Ashland, the following species were found:

Fauna of 1098 F 1.

1. Strophomena rhomboidalis.
2. Orthothetes subplanus.
3. Meristella cf. lævis.
4. Meristella, several species.
5. Rhynchonella cf. stricklandi.
6. Rhynchonella cf. cuneata.
7. Rhynchonella several undetermined species.
8. Rhynchospira formosa.
9. Trematospira cf. globosa.
10. Trematospira cf. formosa.
11. Nucleospira concava.
12. Nucleospira cf. pisum.
13. Spirifer bicostatus.
14. Lichas boltoni.
15. Proetus cf. junius.
16. Avicula textilis.
17. Mytilarca cf. canadensis.
18. Cypricardinia lamellosa.
19. Platyceras, several species.
20. Gastropods, eight undetermined species.
21. Orthoceras sp.

Winslow farm, Ashland.—In a limestone lens on the farm of K. Winslow, Ashland, the following species were found:

Fauna of 1098 K 4.

1. Corals, several undetermined.
2. Strophomena rhomboidalis.
3. Platyceras, small species.
4. Orthothetes sp.

Dudley farm, Castle Hill.—On the Dudley farm, Castle Hill, the following species were found:

Fauna of 1415 L 2.

1. Strophomena rhomboidalis.
2. Stropheodonta varistriata.
3. Leptæna transversalis.
4. Hyatella congesta.
5. Nucleospira pisum.
6. Pentamerus oblongus.
7. Lichas boltoni.
8. Dalmanites limulurus.
9. Palæocyclus rotuloides.
10. Several undetermined brachiopods.

The following specimens from the Dudley farm, same limestone, were collected by Olaf O. Nylander:

Fauna of 1415 L.

1. Atrypa marginalis.
2. Conchidum knighti (cf. nysius).
3. Pentamerus oblongus.
4. Eatonia medialis var.
5. Leptæna transversalis.
6. Spirifer radiatus (= S. nympha Billings).
7. Nucleospira pisum.

Littlefield farm, Chapman.—On the Littlefield farm, in Chapman, the following species were collected:

Fauna of 1099 D 6.

1. Dalmanites limulurus.
2. Nucleospira pisum.
3. Stropheodonta varistriata.
4. ? Cyrtia sp.
5. Brachiopods, several minute species.
6. Corals.

Two drift bowlders (1095 G and H) picked up by Mr. Olaf O. Nylander, the one in Fort Fairfield, the other in Presque Isle, contain the same fauna, viz:

Fauna of 1095 G.

1. Strophomena rhomboidalis.
2. Atrypa neglecta.
3. Atrypa (Whitfieldia) nitida.

Fauna of 1095 H.

1. Conchidum knighti (cf. nysius).

SQUARE LAKE LIMESTONE.

The Square Lake limestone is a gray fragmental limestone, chiefly composed of fragments of corals, crinoids, and more or less perfect fossil shells. The outcrop is on the western shore of Square Lake (or Sedgwick Lake), one of the chain of larger lakes in northeastern Maine. The fossiliferous locality is small and near water level, on the shores of Square Lake, at a position opposite the eastern head of Eagle Lake, in the southwestern quarter of T. 16, R. 5.

The fauna has been collected by several geologists. Specimens of the collection made by C. H. Hitchcock and described by E. Billings are in the Amherst Geological Museum. But the writer believes, from the best information he can obtain, that the types of the descriptions published in the Proceedings of the Portland Society of Natural History were destroyed in the fire which demolished the society's building in 1866 (see p. 31).

The fauna of this particular limestone is clearly distinct from the other limestone faunas of Aroostook County at present known (viz, the

Ashland limestone). It approaches the fauna of St. Helena Island, Quebec, and appears, from what is known of it, to be represented by the limestones in southern Quebec, about Lake Memphremagog.

Petrographically, the Square Lake limestone differs from the Ashland in its freedom from the fractures and faulting which the latter presents wherever seen. This may be a local peculiarity, but it nevertheless serves to confirm belief in the later period of formation, to which the fossils testify.

The collection from Square Lake in the hands of the writer was made by Olaf O. Nylander, and was purchased for the United States Geological Survey. The specimens have been studied in connection with the original description of the fauna by Billings, published in the proceedings of the Portland Society.[1]

A list of the species reported by Billings, and other lists by Bailey and McInnes, are given on a preceding page (p. 32). Most of the specimens of the present collection are recognized as species named by the authors above mentioned. Some of the specimens are not so recognized, or are species new to the fauna. The list is given below, and follows the order of genera adopted by Billings, indicating the cases of identity by reference to Billings's species by number:

Fauna of 1094 A.

1. Favosites sp. (=B1.)
2. Zaphrentis cf. rugulata. (=B2.)
3. Cladopora cf. seriata.
4. Cf. Chœtetes.
5. Cf. Stromatopora.
6. Crinoid stems of several species. (=B4, 5.)
7. Lyriocrinus cf. melissa.
8. Strophomena rhomboidalis. (=B8.)
9. Strophomena punctulifera. (=B9.)
10. Strophomena indenta. (=B10.)
11. Strophodonta cf. perplana. (=B11.)
12. Strophonella leavenworthana. (=?B14.)
13. Cf. Leptæna sp.
14. Orthothetes cf. subplanus. (=?B14.)
15. Orthis subcarinata.
16. Orthis oblata.
17. Orthis cf. eminens. (=?B13.)
18. Orthis, two undetermined species.
19. Orthis cf. discus. (=B12.)
20. Bilobites varica.
21. Rhynchonella mainensis. (=B15.)
22. Rhynchonella nucleolata. (=B16.)
23. Rhynchonella aspasia. (=B17.)
24. Rhynchonella bialveata. (=B18.)
25. Rhynchonella pyramidata.
26. Rhynchonella transversa.
27. Rhynchonella cf. vellicata.
28. Eatonia medialis. (=B20.)
29. Eatonia medialis var.
30. Atrypina imbricata
31. Atrypina cf. disparilis. (=?B21.)
32. Trematospira maria. (=B22.)
33. Trematospira hippolyte. (=B23.)
34. Trematospira multistriata.
35. Trematospira simplex.
36. Rhynchospira electra. (=B25.)
37. Nucleospira pisiformis.
38. Nucleospira ventricosa.
39. Parazyga deweyi. (?=B19) ("Rensselæria Portlandica Bill.")
40. Cf. Cryptonella eximia.
41. Atrypa reticularis. (=B26.)
42. Atrypa reticularis (with fringe).
43. Athyris harpalyce. (=B28.)
44. Athyris sp.
45. Spirifer macropleurus. (=B29.)
46. Spirifer hesione. (=B30.)
47. Meristella princeps.
48. Meristella bella.
49. Meristella lævis.

[1] Proc. Portland Soc., Nat. Hist., Vol. I, Pt. II, 1869, pp. 104-125.

50. Meristella arcuata.
51. Strophostylus cf. elegans.
52. Murchisonia hebe.
53. Platyceras, 8–10 distinct forms (? species). (=B31 and 32.)
54. Gastropods, undetermined. (=?B33.)
55. Orthoceras sp.? (See B34.)
56. Phacops trajanus. (=B36.)
57. Proetus macrobius. (=B37.)
58. Proetus junius. (=B38.)
59. Bronteus pompileus. (=B39.)
60. Lichas bigsbyi. (=B40.)
61. Cypricardinia lamellosa.
62. Lamellibranch, undetermined.

The age of this limestone is distinctly the same as that of the Lower Helderberg formation of New York, as Billings has already stated. The precise correlation of the Square Lake fauna is to be determined by comparison of the two faunas, species by species.

A glance at the lists shows us that there are many species peculiar to the Maine facies, and the question arises: Is it possible to recognize in the Maine fauna the stage of development corresponding to one or other of the stages exhibited by the rich subfaunas of the New York section?

Although the full discussion of the biologic characteristics of these faunas is reserved for a future work, it may be of interest to state here the principles upon which correlation can be established on grounds of biologic evolution alone, and to illustrate them by a typical discussion.

The rhynchonellas of the Square Lake fauna are abundant and well preserved, and we have in the several New York faunas of the Neosilurian and Eodevonian abundant representatives of this genus. Therefore the true rhynchonellas, and the forms which, although distributed in other genera, are evidently, from an evolutional point of view, closely related to them, have been selected.

If fossils can be relied on to signify the stage of evolutional mutation in which they lived, a study of a single group should furnish direct evidence of the stage of the fauna investigated. Many figures have been made in the course of these investigations, and although the subject can be satisfactorily treated only in an elaborate illustrated monograph, the principles of the study and an indication of the importance and definiteness of the results obtained can be indicated, preliminary to the preparation of such a monograph, for which much minute study and a great number of illustrations will be required.

CORRELATION OF THE RHYNCHONELLAS OF THE SQUARE LAKE FAUNA.

GENERIC CHARACTERS.

In estimating the geologic age of any fauna, the biologic relations of the species of each genus may be studied separately, and bear their own testimony as to the position they occupy in the general evolution of the race.

The rhynchonellas are particularly interesting for this purpose, because in the typical New York sections of the Lower Helderberg, which at first glance seems most nearly related to this Square Lake fauna, this genus is represented by an abundance of individuals which have presented a wide divergence of form and size. By examination of the facts we may expect, therefore, to discover the place occupied by the Maine specimens, generically as well as specifically, in the history of the mutation of the race.

The characters of the Rhynchonellidæ as a family were notably differentiated "very early, and have been perpetuated up to the present without departure, at any time, from the early derived type," as Hall and Clarke remarked in 1894.[1] In the family twenty-four genera are recognized by Schuchert.[2] Schuchert's list is a revision of Hall and Clarke's classification of 1893–94.[3]

Of these twenty-four genera, fourteen are represented by Paleozoic species, as follows:

1. Rhynchonella, Fisher de Waldheim, 1809.
2. Rhynchotrema, Hall, 1860.
3. Rhynchotreta, Hall, 1879.
4. Camarotœchia, Hall and Clarke, 1893.
5. Leiorhynchus, Hall, 1860.
6. Wilsonia, Kayser, 1871.
7. Uncinulus, Bayle, 1878.
8. Hypothyris, King, 1848 (not Phillips, 1841).
9. Pugnax, Hall and Clarke, 1893.
10. Eatonia, Hall, 1857.
11. Cyclorhina, Hall and Clarke, 1893.
12. Rhychopora, King, 1856.
13. Terebratuloidea, Waagen, 1883.
14. Orthorhynchula, Hall and Clarke, 1893.

Of these genera, the following are reported from rocks of the Lower Helderberg or Oriskany age in North America, viz: Rhynchonella, Rhynchotrema, Camarotœchia, Wilsonia, Uncinulus, Eatonia. The genus Rhynchotreta contains no species of as late age as Lower Helderberg. The genera Leiorhynchus, Hypothyris, Pugnax, Cyclorhina, Rhychopora, and Terebratuloidea, so far as present knowledge extends, have no species as early as the Oriskany.

In the discussion of the correlation of the Square Lake fauna, which contains an Eatonia, we are thus restricted to six genera: Rhynchonella, Rhynchotrema, Camarotœchia, Wilsonia, Uncinulus, and Eatonia. Eatonia may be removed from the discussion for the time on account of its marked difference from the other forms. It is important, first, to ascertain what are the generic characters of the other five groups, since the characters for determining the particular age must be sought among those which are subordinate to generic rank.

Of these genera, Eatonia is represented in the Square Lake fauna by numerous specimens of *Eatonia medialis*. This species is also abundant in the Delthyris Shaly limestone of eastern New York. As

[1] Pal. New York, Vol. VIII, Pt. II, p. 342.
[2] Bull. U. S. Geol. Survey No. 87, p. 121.
[3] Rept. State geologist New York, Vol. [illegible]I. 1893, p. 935; and Pal. New York, Vol. VIII, Pt. II, 1894, p. 365

the genus is not reported at a lower stage than the Lower Helderberg,[1] and the species is not known from a lower horizon than the Delthyris Shaly limestone, the presumption is strong, from this evidence alone, that the Maine fauna is not much older than the Delthyris Shaly limestone of the New York section.

Of the family Rhynchonellidæ, the following genera are recognized in America at lower horizons than the Lower Helderberg:

Orthorhynchula	Ordovician.
Rhynchotrema	Ordovician.
Rhynchotreta	Silurian.
Camarotœchia	Ordovician-Silurian.
Wilsonia	Silurian.
Uncinulus	Silurian.
Rhynchonella	Silurian.

Thus it is shown that the ancestral origin of the Lower Helderberg forms must be sought within these seven genera.

The only species of Uncinulus reported from below the Lower Helderberg is *U. stricklandi*, from Waldron, Indiana, Louisville, Kentucky, and strata of Niagara age. Rhynchotrema is abundantly represented in the Ordovician by *R. capax*, reported from Indiana, Ohio, Illinois, Missouri, Wisconsin, Iowa, Minnesota, Anticosti, Manitoba, and Hudson Bay. The closely allied species *R. inæquivalve* is reported from the Trenton of Drummonds Island, New York; Kentucky; Tennessee; Illinois; Wisconsin; Iowa; Minnesota; New Mexico; Ottawa, Canada; Manitoba; and a few other species are reported; but no species of this genus is recorded from the lower horizons of the Silurian. The Lower Helderberg form *R. formosa* is the latest representative of the genus recorded for America. The genus is thus characteristically Ordovician in age, and the propriety of referring the Lower Helderberg species to the genus calls for careful examination.

The fact that the small specimens referred by Hall[2] to *Rhynchotrema formosa* in the Delthyris Shaly limestone of New York can not be distinguished from specimens of the Square Lake fauna which are here referred to *Rhynchonella aspasia*, makes it probable that rhynchonellas of this type may be the direct descendants of the rhynchotremas of the earlier formations. More study, however, will be necessary to confirm this view.

By this method of exclusion we are restricted to the species catalogued under the names Rhynchonella, Orthorhynchula, Rhynchotreta, Camarotœchia, Wilsonia, and Uncinulus for the probable ancestors of the rhynchonellas of our fauna. The most characteristic rhynchonellas of the New York Lower Helderberg are referred to the group called Uncinulus by Bayle.[3]

[1] In the present paper this genus is reported from the limestone of Castle Hill, 1415 L, in association with species which signify Niagara age. (See p. 54.)

[2] Pal. New York, Vol. III, pl. 35, fig. 3.

[3] See Hall and Clarke, 1891 and 1893, and Schuchert, 1897.

Orthorhynchula and Rhynchotreta are so far differentiated from the dominant characters of the rhynchonellids that they may be omitted from the present treatment as reaching their full specialization in the Niagara, and not having direct descendants in the later formations.

The genus Rhynchonella, although strictly speaking having no representatives in the Paleozoic, is still left for the reception of all the species whose characters are not sufficiently well differentiated from the general family characters of the Rhynchonellidæ to have furnished any specialist the means of erecting a new group for them. It is quite possible that the Maine rhynchonellas described as *R. aspasia* by Billings were descended from some one of these earlier rhynchonellas not yet separated into special (literary) groups. The other group, Uncinulus Bayle, into which a large majority of Lower Helderberg species falls, has for its possible ancestors species of Wilsonia, Camarotœchia, and the remnant, not distributed, of Rhynchonella.

CAMAROTŒCHIA Hall.

According to the definitions grouped under this name, the distinctive characters by which it is marked seem to be: (1) The absence of a cardinal process; (2) a median septum in the brachial valve, so divided as to make a cavity between the teeth before reaching the outer wall of the shell. On these grounds Hall and Clarke include *R. ventricosa* in Camarotœchia, but they distribute all the other rhynchonellas in other subdivisions. In their final revision of the Brachiopoda these authors state that "the structure of Camarotœchia is possessed by the extravagantly gibbous species *R. ventricosa*."[1] The forms of the Lower Helderberg most closely related to those called Camarotœchia below and above that horizon are distributed in another group, called Uncinulus, and the three characteristic rhynchonellas of the Oriskany are again gathered into the Camarotœchia group.

This omission of the camarotœchias, except the one species, from the Lower Helderberg faunas is explained by these authors as follows:

> At the appearance of the Lower Helderberg faunas, with their multiplicity of rhynchonellids, this type of structure appears to have yielded somewhat to the robust forms possessing a cardinal process which are referred to the genus Uncinulus.[1]

It has already been stated that the Lower Helderberg fauna is remarkable for the abundance of the rhynchonellas of the Uncinulus type. These forms in all their superficial characters seem to be in the line of passage from the rhynchonellas, called Camarotœchia, below and above the Lower Helderberg. It is difficult for one accustomed to recognize genetic affinity in successive faunas not to regard the forms of Uncinulus of this period as the direct descendants of rhynchonellas of the Camarotœchia and Wilsonia type in the earlier

[1]Pal. New York, Vol. VIII, Pt. II, p. 191. [2]Op. cit., pp. 190-191.

Silurian, and as the ancestors of the forms called again Camarotœchia in the Oriskany and later periods.

In the Oriskany, with no Uncinulus, this group of shells is called Camarotœchia by Schuchert, although referred to still another group by Hall and Clarke (i. e., Plethorhyncha).[1] It becomes, therefore, of special interest to ascertain the meaning and taxonomic value of those characters which are used to differentiate these several groups, viz, Wilsonia, Camarotœchia, and Uncinulus.

Wilsonia is said to have no cardinal process, but median septum and dental lamellæ like Camarotœchia.

Uncinulus is said to have a cardinal process, like Camarotœchia, and the median septum is described as present; but the slight division of the septum, which is described in Camarotœchia as forming a chamber between the teeth, is not distinctly seen in the typical Uncinulus.

A critical analysis of the characters upon which the several divisions of the rhynchonellas here concerned are based develops the fact that the distinctions are formed on various degrees of development of three internal characters—(1) the cardinal process, (2) the dental lamellæ, and (3) the median septum.

The cardinal process is described as absent in Camarotœchia, Wilsonia, and Rhynchonella; present and linear in Orthorhynchula, Rhynchotrema, and Rhynchotreta; well developed in Uncinulus, and large in Eatonia.

The dental lamellæ are described as absent in Orthorhynchula, Rhynchotrema, Uncinulus (?), and Eatonia, and as present in Rhynchotreta, Camarotœchia, Wilsonia, and Rhynchonella.

In the dorsal valve the median septum is described as thick in Rhynchotrema, prominent and divided in Rhynchotreta, prominent and with slight chamber in Camarotœchia, present or absent in Uncinulus, rudimentary in Hypothyris, short and bifid in Eatonia, and present in Rhynchonella.

It will be noticed that those forms which are conspicuous in the Lower Helderberg are characterized by well-developed cardinal process, by absence of the dental lamellæ, and by rudimentary development of the median septum.

When this diagnosis is compared with the forms which are chiefly confined to formations earlier than the Lower Helderberg, it is to be noted that in regard to the first and third characters there is a definite departure from the earlier stage of development; in the second case there is no indication of sequence, so far as the definitions go.

In both the first and second characters the forms called Camarotœchia assume the characteristics of the earlier types. When this observation is associated with the well-known prominent development of the rhynchonellas, both in size and in numbers, in the Lower Hel-

[1] Pal. New York, Vol. VIII, Pt. II, p. 191.

derberg fauna, it becomes evident that we have here an expression of acceleration in development along the very lines of normal evolution, and associated with favorable conditions of environment, which are expressed in the vigorous fertility and growth of the individuals of the race.

This leads to the remark that the described distinctions, which make it appear that there were very few, if any, camarotœchias in the Lower Helderberg faunas, though they were abundant below and above, are not, properly speaking, generic characters, but are mutations expressing temporary adjustment of the organisms to the environmental conditions, which in the next stage were dropped. To use these names as they are applied by the authors, the evidence makes it probable not only that the Uncinulus of the Lower Helderberg descended from the camarotœchias of the earlier faunas, but that the camarotœchias of the following Oriskany were in direct line of descent from the same genus, Uncinulus.

This interpretation implies, of course, that these characters, which are taken by the authors to be of generic value, are really plastic characters, which are variable in the whole race of rhynchonellas, and that their particular expression is a reflex of environmental conditions and is not an inherited characteristic. The truth of this proposition is confirmed by studying other forms.

When the Oriskany species are critically studied, not only is great development observed, but also great plasticity of the same parts. The spirifers, the rensselærias, the orthids, and the strophomenoids are all conspicuous not only for their great size but for the great development of their parts about the interior of the beak, hinge, and surfaces of muscular attachments; and not only this, but a series of *Spirifer arenosus* exhibits great plasticity in the relative strength of development of internal features, not only in series living together and of the same size and age, but in the degree of development at corresponding stages of growth on different individuals. This plasticity is not confined to Spirifer; the other vigorous species, rensselærias and orthids, show the same feature.

Another fact points to the probability that the taxonomic importance of these characters, as at present defined, is overdone, if not altogether erroneous. In their most valuable revision of the Brachiopoda, Hall and Clarke state that the genus Rhynchonella is, from a literary point of view, rightly restricted to forms of the type *R. loxia*, none of which are known to occur at horizons older than the Mesozoic. Nevertheless, when it comes to distributing, in this same literary way, the rhynchonellids of the Paleozoic under some name, ninety-five American Paleozoic species still have to be called Rhynchonella.[1] The most patent reason for this inconsistency is that in these ninety-five species

[1] Vide Schuchert.

the internal characters are not known, and another set of characters, those of external form and surface markings, still form the basis of the naming and of the taxonomic distribution of the species. There is no question as to the great importance of these internal characters for purposes of determining the genetic relationship of organisms, but it is also a fact that the external or surface characters do not cease to be of similar value.

The old use of external characters failed to give a correct classification in some cases, either because the differences were not discernible from the previously observed characters, or because they were not rightly interpreted. In the first case more evidence was all that was needed to settle the difficulty; but faulty interpretation of their meaning can be made regarding the internal as well as the external characters—the important as well as the trivial characters.

But the point to which attention is called by these remarks is that the taxonomic rank of characters rests primarily upon their relative fixity, and not upon their supposed importance in the individual economy of the organism. If any character suffers mutation in transmission it can not be counted as of high taxonomic value. This does not mean that a particular part or organ of an organism which is possessed by, let us say, all the members of an order does not vary, but that that particular in which the part varies is not an ordinal character, but is only of specific or varietal value.

When we observe, as we do in the Oriskany, nearly every different genus represented by individuals which are large and coarse when compared with their fellows in other formations, the element of size is shown to be of insignificant taxonomic value. So when we observe the relative strength of development of muscular attachments and processes associated with the manipulation of the two valves of a hinged brachiopod, varying at the same stage of growth in individuals of the same species, it is evident that characters based upon proportionate strength of development of such parts can not be relied upon for generic distinctions.

The wilsonias and Uncinulus constitute a characteristic group of rhynchonellas in the early and, particularly in the later, Silurian faunas. But a comparison of these forms with each other shows that the wide range of variability of the characters which are used to distinguish them as groups is more characteristic than any or all of the characters by which their diagnosis is attempted. It is true that specimens can be picked out illustrating the characters described, but it is as true that specimens can be easily found in full collections which can not be discarded from the group but which lack one or other of what are described as typical characters.

Generic characters, to be of taxonomic value, must be distinguished from variatal and specific characters by their greater fixity, or what

PLATE I.

PLATE I.[1]

RHYNCHONELLAS OF THE SQUARE LAKE LIMESTONE.

(Numbers in parentheses refer to catalogue numbers of the specimens figured.)

Figs. 1, 5, 9. Dorsal, front, and ventral views of broad, flat form of *Rhynchonella vellicata* Hall. (M 45.)

Figs. 2, 6, 10. Dorsal, front, and ventral view of median form of *Rhynchonella vellicata* Hall. (M 45.)

Figs. 3, 7, 11. Dorsal, front, and ventral view of narrow form of *R. vellicata* Hall. (M 45a.)

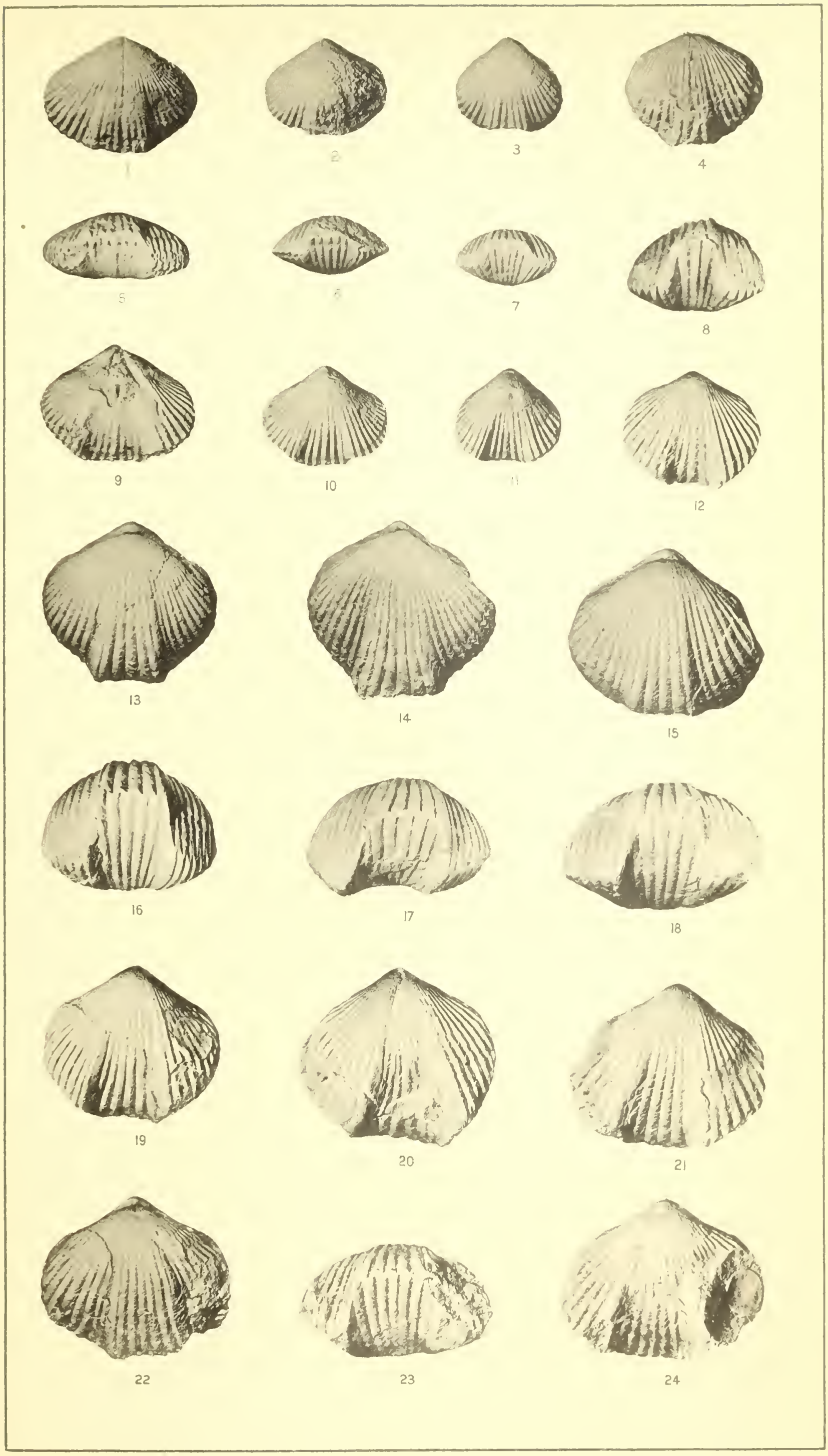
Figs. 4, 8, 12. Dorsal, front, and ventral view of a form intermediate between Hall's *R. vellicata* and *R. mainensis* Billings, labeled *R. mainensis* Bill. var. (M 21).

Figs. 13, 16, 19. Dorsal, front, and ventral view of a very perfect specimen of *R. mainensis* Bill., near the form of Billings's type. (M 22.)

Figs. 14, 17, 20, and 15, 18, 21. Dorsal, front, and ventral views of the broader, flatter forms of *R. mainensis* Billings. (M 19.)

Figs. 22, 23, 24. Dorsal, front, and ventral views of *R. mainensis* Billings, approaching the form *R. abrupta* Hall. (M 19.)

[1] The original figures from which Pls. I and II were prepared were made directly from the specimens by a patented photographic process by N. W. Carkhuff.



RHYNCHONELLAS OF THE SQUARE LAKE LIMESTONE.

THE HELIOTYPE PRINTING CO., BOSTON.

PLATE II.

PLATE II.

RHYNCHONELLAS OF THE SQUARE LAKE LIMESTONE.

(Numbers in parentheses refer to catalogue numbers of the specimens figured.)

Figs. 1, 4, 7. Dorsal, front, and ventral views of *R. mainensis*, var., with characters intermediate between that form and *R. mutabilis* Hall and *R. nucleolata* Hall. (M 22.)

Figs. 2, 5, 8. Dorsal, front, and ventral views of a broad, short beaked form of *R. mainensis* Billings. (M 19.)

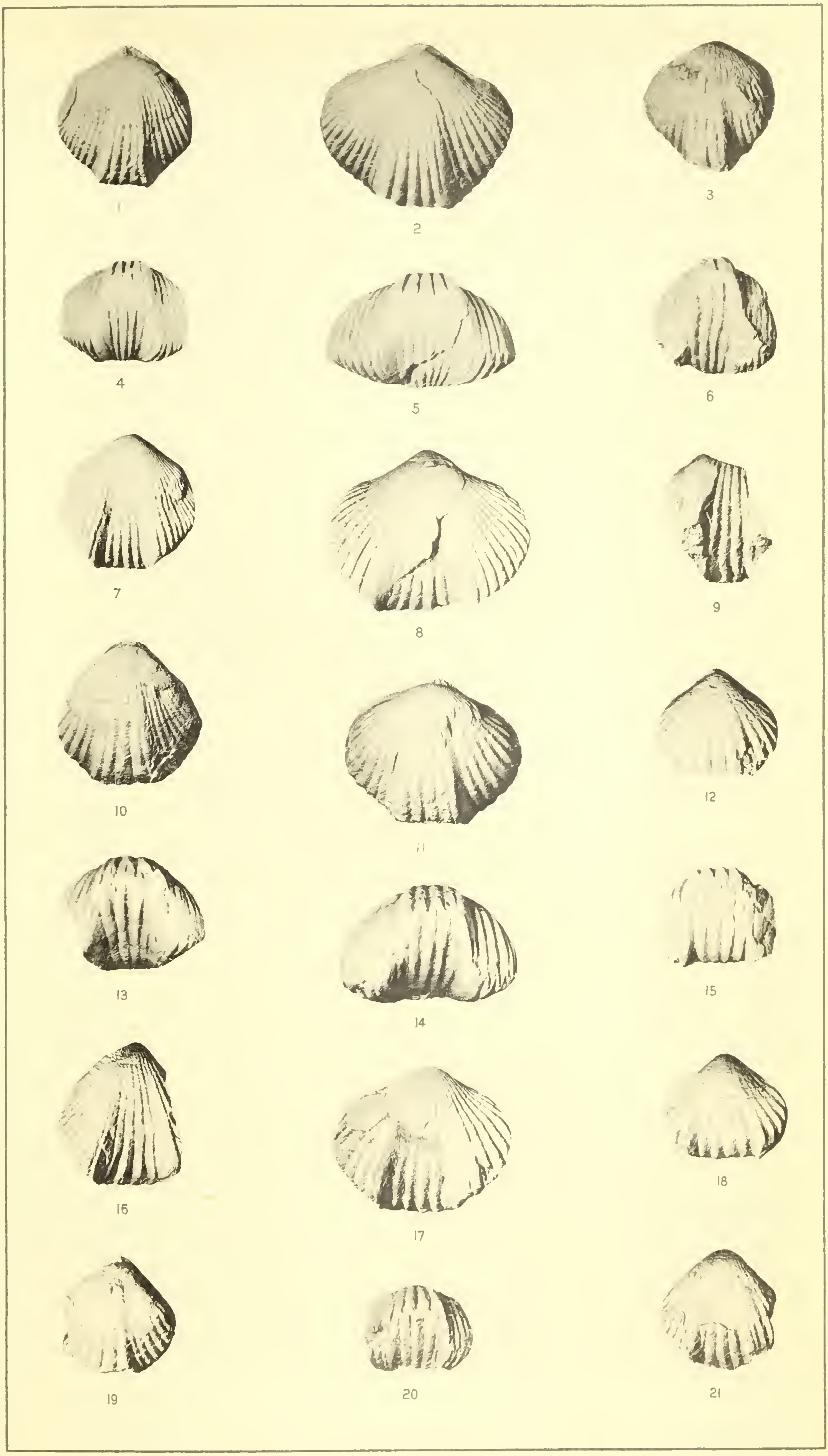
Figs. 3, 6, 9. Dorsal, front, and ventral views of *R. nucleolata* Hall. (M 23.)

Figs. 10, 13, 16. Dorsal, front, and ventral views of *R. mainensis*, var., approaching *R. nucleolata* Hall. (M 21.)

Figs. 11, 14, 17. Dorsal, front, and ventral views of a typical form of *R. mainensis* Billings. (M 22.)

Figs. 12, 15, 18. Dorsal, front, and ventral views of *Rhynchonella pyramidata* Hall. (M 20.)

Figs. 19, 20, 21. Dorsal, front, and ventral views of *R. nucleolata* Hall, of the form figured by Billings. (M 23.)



RHYNCHONELLAS OF THE SQUARE LAKE LIMESTONE.

THE HELIOTYPE PRINTING CO., BOSTON.

may be defined as their more exact reproduction or transmission in generation. What distinguishes these Lower Helderberg rhynchonellas as a whole is their great luxuriance and fertility, together with a great plasticity in the very characters which have been selected for both specific and generic diagnosis. This plasticity and increased range of variation, associated with the evidence of favorable conditions of life, does not point to restriction of the interbreeding which is supposed to distinguish specific groups, and it certainly does affect separate genera.

With these remarks upon the generic characters, we may next examine the particular species present in the fauna and discuss their significance for purposes of correlation.

SPECIES OF RHYNCHONELLIDS IN THE SQUARE LAKE FAUNA.

(See Pls. I and II.)

In the Square Lake fauna there are a considerable number of forms which fall at once into the Rhynchonella group of brachiopods, and which, upon a slight comparison with described species, are seen to be closely allied to species of Rhynchonella of the Lower Helderberg formation. In order to determine the geologic horizon of the fauna, not only is it necessary to determine the identity of these species, but, whether identical or not, it is necessary to ascertain the precise stage in the evolution of each phylum, or race, to which the particular species belong. This may be reached by ascertaining how these particular species are related morphologically to forms whose place in a typical geologic section, such as that of New York, is known.

The following species of Rhynchonella have been recognized in the Square Lake fauna by Billings, and later by the writer:

Rhynchonella mainensis Billings, M 19, M 22.
Rhynchonella nucleolata Hall, M 23.
Rhynchonella pyramidata Hall, M 20.
Rhynchonella pyramidata Hall var. a, M 24.
Rhynchonella vellicata Hall, M 45.
Rhynchonella aspasia Billings, M 26.
Rhynchonella bialveata Hall.
Rhynchonella transversa Hall.

There is no difficulty in recognizing, in the collection under investigation, specimens similar to those referred to by Billings in his original description of the fauna. Because of the rarity of the volume in which the species were originally described (the papers as well as the specimens having been burned in the fire which destroyed the Portland Society building in 1866), Billings's original description is here transcribed:

RHYNCHONELLA MAINENSIS, n. sp.

Pl. III, fig. 4, *Rhynchonella mainensis*, n. sp.

Description.—Transversely ovate, length about one-fifth or one-sixth less than the width. Ventral valve moderately convex, most elevated at about one-third the

length from the beak; mesial sinus deep in front, flat in the bottom, the side sloping outward, becoming obsolete at two-thirds the length of the shell; beak well defined, incurved down to the umbo of the dorsal valve; on each side of the beak a small ovate excavation extending toward the cardinal angles; umbo only slightly elevated, this valve being only half a line longer than the dorsal. Dorsal valve strongly and uniformly convex, nearly hemispherical, most elevated in the upper half, with a wide flat mesial fold elevated about one line above the general surface at the front margin, but becoming obsolete at two-thirds of the length; beak pointed, well defined, but only visible when that of the opposite valve is broken away.

Surface with from twenty-five to thirty ribs, of which there are from four to six on mesial fold and from three to five in the sinus. All the ribs die out before reaching the beak, the upper one-fourth of the shell being smooth. On approaching the front margin the ribs are obscurely angular, but toward the upper part of the shell they are neatly rounded but not strongly elevated.

Width, ten to twelve lines; length, about one-fifth or one-sixth less than width; depth of both valves, six to eight lines; depth of the sinus in the front margin of the dorsal valve, about three lines.

The curvature of the ventral valve from the beak along the median line and the bottom of the sinus is a uniform arch somewhat most abruptly curved in the upper half. This curve can not be seen in the profile of the whole shell, as it lies partly in the sinus.

This species is closely allied to *R. abrupta* Hall, Pal. N. Y., vol. 3, p. 228, pl. 32, fig. 3, but differs therefrom in being more ventricose in the upper part of the dorsal valve, in having the ventral valve uniformly arched along the sinus instead of abruptly bent upward nearly at right angles to the dorsal valve, and in not having the ribs in the sinus bifid at their extremities.

Locality and formation.—Square Lake, Maine; Upper Silurian.[1]

RHYNCHONELLA NUCLEOLATA Hall.

R. nucleolata Hall, Pal. N. Y., vol. 3, p. 227, Pl. XXI, figs. 1 and 2. Pl. III, fig. 5. *Rhynchonella nucleolata; a*, dorsal, *b*, front, and *c*, side views.

Description.—This species is smaller than *R. mainensis*, and has the surface marked by only fifteen or twenty ribs toward the front, the upper part being smooth. The outline is subcircular or subpentagonal; the width varies from a little less to a little greater than the length. Ventral valve depressed convex, a small portion of the margin abruptly deflected to meet the margin of the dorsal valve; the mesial sinus becomes obsolete about the middle of the shell, but on approaching the front margin the portion of the shell constituting the bottom of the sinus is suddenly bent almost at right angles to the plane of the lateral margin and forms a projection which fits into a deep oblong notch of the opposite valve. Beak small, pointed, apparently incurved so as just to cover that of the dorsal valve. (It is not well preserved in the specimen examined.) Dorsal valve very convex, strongly elevated in the first half, where there is a short mesial fold; the upper half of the shell varies greatly in the amount of its gibbosity, being in some depressed convex, and in others rather strongly and broadly tumid; beak angular, prominent, but concealed beneath that of the ventral valve. There is a short mesial septum extending from the beak of this valve nearly half the length, which can be distinctly seen when the shell is partially or wholly removed.

Of this species there are only two good specimens in the collection from Square Lake. It is very difficult to say whether they should be referred to *R. nucleolata* or to *R. pyramidata*. One of them has the dorsal valve strongly convex in the upper

[1] Proc. Portland Soc. Nat. Hist., Vol. I, Pt. II, p. 110.

half, and the other depressed convex, but they both unquestionably belong to the same species.

Locality and formation.—Square Lake, Maine; Upper Silurian.[1]

RHYNCHONELLA ASPASIA.

Pl. III, fig. 6, *Rhynchonella aspasia.* Dorsal and side views of a young individual. The large specimens have the base not so distinctly rectangular, but a little rounded.

Description.—Transversely subelliptical; greatest width about one-fourth more than the length. Ventral valve narrowly convex on the umbo; a mesial sinus commencing at about one-fourth of the length from the beak, and growing deeper with an uniform curve to the front margin, where it is full one-half the whole width of the shell and deeply indents the opposite valve; on each side of the sinus one or two ribs more prominent than the others; outside of these the surface is depressed convex, and shows a tendency to become slightly concave close to the margin; beak small, closely incurved and nearly, if not quite, in contact with the umbo of the opposite valve. Dorsal valve rather strongly but narrowly convex along the median line; sloping to the sides; mesial fold strongly elevated in front, dying out at about half the length. Surface in young specimens with seven or eight strong angular ribs on each valve; one rib in the sinus and two on the mesial fold. In old specimens, about twelve ribs on each valve, of which there are two or three in the sinus and three or four on the fold.

The greatest width is about the middle of the shell. On a side view of a young shell the most elevated point of the dorsal is just at the front margin on the top of the fold, and the base has a rectangular form. In the old specimens, on a side view, the front is not so decidedly angular, but slightly rounded. Width of the largest specimen, 7 lines; length, 6 lines. Width of the smallest specimen, $4\frac{1}{2}$ lines; length, $3\frac{1}{2}$ lines.

This species is allied to both *R. altiplicata* and *E. acutiplicata*, Hall, Pal. N. Y., vol. 3, Pl. XXXIII, and seems to stand between them. It is proportionally wider than the former and not so numerously ribbed as the latter. It may be that a greater number of specimens would afford us the means of uniting all three.

Locality and formation.—Square Lake, Maine; Upper Silurian.[2]

The typical *Rhynchonella mainensis* Billings[3] is plainly a representative of *R. abrupta* Hall of the Delthyris Shaly limestone of New York. The first distinctive character noted by Billings is the greater ventricosity in the upper part of the dorsal valve of the Maine species. This is a character belonging to the earlier form *R. mutabilis.* At the Delthyris Shaly limestone stage of mutation, of the forms with the higher number of plications, *R. abrupta* is the extreme in this character of early gibbosity. The extreme of gibbosity at this stage pertains to the forms with fewer plications, as *R. nucleolata.* This variation is less extreme in *R. vellicata*, and among the few specimens in the present collection there are those passing to *R. vellicata*, and even thinner than the typical *R. vellicata* of New York.[4]

If the modification were associated purely with geologic range it would be inferred that the Maine fauna was younger than the *R. mutabilis* stage in New York, and older than the *R. abrupta* stage.

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[1] Proc. Portland Soc. Nat. Hist., Vol. I, Pt. II, p. 110.

[2] Op. cit., Vol. I, Pt. II, p. 111.

[3] See Pl. II, figs. 11, 14, 17.

[4] See Pl. I, figs. 1, 5, 9.

But, judging from the wide range of plasticity expressed in specimens of the Delthyris Shaly limestone, as well as in those of the Square Lake limestone, it is assumed that the limits of plasticity of this character were as great in the Delthyris Shaly limestone as in the Maine representatives, and that the difference in the description is chiefly subjective and depends upon the selection of type specimens made by Billings for his species *R. mainensis*.

The second distinctive character noted by Billings is "the ventral valve uniformly arched along the sinus, instead of abruptly bent upward nearly at right angles to the dorsal valve." This is a characteristic of all the Square Lake representatives, except *R. pyramidata*.[1] But, as between the *R. mutabilis* and *R. abrupta*, the Maine forms are decidedly nearer the mutation *R. abrupta* than *R. mutabilis*.

The third character mentioned by Billings—the absence of the bifid extremities of the plications—is not a constant character, as some of the Square Lake specimens are bifid at the extremities.[2] This character is associated with the abruptness of the bending of the surface at the front. In forms of the *R. pyramidata* type this character is conspicuous; and, also, on a comparison of the successive mutations of the series, it is observed to be more conspicuous with advance of time. From such a comparison it seems probable that the angularity of the front, the sharp bifid development of the terminal part of the plications, the general flattening of the shells during the first half of the growth, and the dominance of the fewer-ribbed specimens, are characters associated with advancing evolution, and hence are more conspicuous at the later stages of mutation.

Passing from the characters of typical *R. mainensis* of Billings to closely allied forms associated together in the Square Lake fauna, the range of variation covers the same characters expressed by the variations in the Delthyris Shaly limestone series. On the other hand, the variant with the high number of plications, flat form, and low sinus and fold, called *R. vellicata* by Hall, is well represented in the Square Lake fauna;[3] also the forms with fewer plications but gibbous form, the variant *R. nucleolata* Hall, and those with few strong plications, angular beak, abrupt geniculated front, called *R. pyramidata* Hall, are represented together in the collection in hand. That these differences are purely variational is well shown by two specimens in the Square Lake fauna.

The first is a specimen of *R. nucleolata* (23/M),[4] which, on the young part of the shell about the beak, exhibits the full quota of plications, twenty-eight to thirty being clearly visible. Upon passing a prominent concentric line of growth in midst of shell the plications lessen, and at the front the number that can be counted is but eighteen, thus

[1] See Pl. II, figs. 12, 15, 18.
[2] See Pl. II, figs. 13, 15.
[3] See Pl. I, figs. 1–12.
[4] Pl. II, fig. 21.

showing the variational tendency to diminish the number of plications, which is a conspicuous feature of the dominant representatives of the race when looked at in geologic succession.

The second specimen is a variety of *R. pyramidata*,[1] which typically exhibits few plications as soon as they are evident in the beak region. This variant is much narrower in form than the typical specimens, and exhibits but a single plication in the fold instead of three, as is usual, and only four on each side, the typical number being five. In this case the central plication is longer and more prominent and more elevated from the surface than is usual. If this were represented by many individuals holding these characters without variation, it would undoubtedly be considered as a good species; but if we regard the rhynchonellas of this group as particularly plastic in these elements of form, the specimen is to be regarded as a marked variational form of the *R. pyramidata* type, carrying its peculiarities of *R. pyramidata* a step further away from the central form in the direction of the variation which the normal *pyramidata* has assumed. Both of these aberrant forms are evidence of the nature of the plasticity among the individuals living together at the time of the Square Lake limestone.

When it is observed that the same characters are those upon which dominant groups of individuals, called species, are founded, not only in this fauna, but in the several New York faunas of the Lower Helderberg, it becomes evident that what constitutes the limitation of a species is the checking of the plasticity of the several characters at the same point in numerous individuals.

This characteristic of specific groups is brought out by comparing species of successive faunas. In a single fauna, like this Square Lake fauna, it is possible to see only the combination of characters marking the dominant forms and those divergent forms associated with them which, because of their rarity, are clased as varieties. In a series of successive faunas it is also possible to see the changes in combination of characters marking the successive species, each successive species bearing the relation of mutant to the earlier forms, but the dominant combination is not a direct mutant of the earlier dominant forms, but may be a mutant of some of the inconspicuous varieties.

In the New York Lower Helderberg we find a convenient series upon which to make these observations. The rhynchonellas of this general group are described by Hall under the following names:[2] For the Lower Pentamerus fauna, *R. mutabilis* Hall; for the Delthyris Shaly limestone, *R. nucleolata*, *R. abrupta*, and *R. vellicata* Hall; for the Upper Pentamerus, *R. ventricosa*, *R. nobilis*, and *R. campbellana;* for the Oriskany, *R. speciosa;* and other species may be added, but their divergence is so extreme as to bring in other questions which may be

[1] Not figured on these plates.

[2] See Pal. New York, Vol. III.

left for remark at another occasion. The following deductions may be drawn:

1. These several described species evidently belong to a common race, whatever other species may belong to the same race, or whatever opinion we may have as to their generic relations.

2. It is also clear that the dominant characteristics of *R. mutabilis* of the first stage are represented at the second stage by *R. nucleolata*, at the third stage by *R. ventricosa*, and at the fourth stage by *R. speciosa* in part.

4. *Rhynchonella mutabilis* of the first stage has the plications low, rounded, and not sharply developed; it shows various degrees of convexity, but marked gibbosity is the dominant characteristic; the fold and sinus are low and inconspicuous. The curvature of surface is gradual and even, so that nowhere does the surface present any marked or abrupt angles—i. e., any marked and sudden changes in the direction of growth of the shell. There is considerable variation expressed, but these characters prevail so dominantly among them all that there seem to be no characters by which to break up the series into separate specific groups. When the succeeding species are compared with this one, the differences are seen to consist chiefly in the intensifying of characters which are expressed here in a medium stage of development.

4. There are evident at the second stage, the Delthyris Shaly limestone, three dominant forms (*a*, *b*, *c*) which are closely related to *R. mutabilis*, but differ by the intensifying of the central and the two extremes of character-combinations seen in that species. These are:

a. The median type, which preserves the full complement of plications, but they are more sharply defined upon the surface. The gibbosity is distinctly less, though still conspicuous; the fold and sinus are well defined on the latter half of the growth of the shell, and the front is rather abruptly angulated, though not strongly so. This is called *R. abrupta*, and in the thinner forms *R. vellicata*.

b. The extremely gibbous forms, which have a reduced number of plications that are fainter at the beak but become stronger with growth and more angular; the fold and sinus are well defined on the mature half of the shell. This is *R. nucleolata*.

c. The form with least tendency to gibbosity, which grows directly from the beak, with flat surfaces, slightly arched plications, few and not evident at first, but well defined toward the front; the fold and sinus not sharply developed till late in the growth; and finally at the edge along the sides and at the front a sharp angular turn in growth, making a flat, almost square, front and sides. This is *R. pyramidata*.

5. The third stage shows two dominant forms:

a. The median type is further elaborated by an increased growth to the front, making an oval-elongated species with full complement of plications, well defined; the fold and sinus evident at front, and the

latter half of the growth larger in size, thus making a narrow form with sharper beak. This species is *R. nobilis.*

b. The second dominant group of the Upper Pentamerus is a further mutation of *R. nucleolata* of the preceding stage; the plications are still fewer, and the gibbosity is still more extreme. This is *R. ventricosa.*

6. In the Oriskany the elongate-oval form is an expression of the same tendency seen in *R. nobilis*, but it is associated with smaller number of ribs and less dominant fold and sinus and much greater size than in the Lower Helderberg forms. This is *R. speciosa.*

A study of the plications on the forms from the several Lower Helderberg localities of New York shows the intimate relationship between the evolution of these characters and the ages, or, more strictly, successive stages in geologic history, at which they occur.

Without going outside of the published report of the facts as found in Vol. III of the Paleontology of New York, the following points are in evidence:

A. *R. mutabilis* is reported as having twenty to twenty-six plications in all, and six to eight on the fold. This is the Lower Pentamerus species.

B. *R. pyramidata*, thirteen to twenty-two, and foui to six on fold.
R. nucleolata, fifteen to twenty-three, and four to five on fold.
R. abrupta, twenty-five to thirty-three, and seven to eight on fold.
R. vellicata, twenty-four to thirty-six, and six to eight on fold.

These are the Delthyris Shaly limestone species. It will be observed that *R. mutabilis* is strictly intermediate, and the first two species are different by having less and the second two by having more plications than the earlier species.

C. The next series are from the following stage, the Upper Pentamerus:

R. ventricosa, fourteen to twenty, and three to four on fold.
R. campbellana, twenty-two to twenty-four, and five to six on fold.
R. nobilis, twenty-six to thirty-two, and six to eight on fold.

This set exceeds the extremes of the set of the preceding stage in some particulars, but the limit of variation in each case is less. This latter characteristic, which may be described as a tendency to restriction of variation, is to be observed in a collection of specimens by the fact that the specimens in a collection of *R. ventricosa* are more uniform than those in a similar collection of the species *R. pyramidata;* or a set of specimens of *R. nobilis* may be said to be more uniform than a set of specimens of *R. vellicata.*

D. When we pass up to the Oriskany the plications are conspicuously increased, with decided increase in the size of the specimens.

Again taking the reported statistics, supplementing them with a

count of the plications as figured for *R. speciosa* and *R. multistriata*, we find the following:

R. speciosa, twenty-seven to thirty-three plications, not bifurcating on body of shell.
R. barrandi, thirty to forty plications, rarely bifurcating.
R. ramsayi, thirty-six to forty plications.
R. pliopleura, sixty-seven to seventy plications, bifurcating.
R. fitchana, seventy-five plications, bifurcating.
R. principalis, eighty plications, occasionally bifurcating.
R. oblata, seventy-five to eighty plications, occasionally bifurcating.
R. multistriata, seventy-five to eighty plications, bifurcating, finely striate.

Before a careful study of these facts (upon actual series of specimens) is made it would be unscientific to attempt to state the actual limits of specific variation; but it is evident that the Oriskany species are as a series more numerously plicated; the fold and sinus, particularly, hold more plications; the size of the specimens is greater and the bifurcation of the plications is a common characteristic, causing them to differ from the series of forms which, on the theory of descent, must be supposed to contain their ancestors.

Without, at the present time, turning aside to investigate the actual facts regarding the New York Helderberg series, it is evident that the morphologic mutation which the representatives of this group of rhynchonellas expressed included the following particulars:

The variations which were expressed by the individuals of the Lower Pentamerus single species *R. mutabilis* were carried to the extent of making greater divergence of form in the Delthyris Shaly limestone stage. In the Upper Pentamerus the extremes were still greater, but the variation was less, and the dominance in number of individuals is among the extreme and not the median types.

In the Oriskany the characteristic mutation resulted in great size of individuals, associated with which was a decided increase in the number of plications, chiefly by bifurcation. This last fact, if taken in connection with the normal variability or, more strictly speaking, plasticity in the number of plications, suggests the inference that the increment in the number of plications is associated with expansion of the surface of the shell laterally. In case this took place very early in development, bifurcation resulted with growth. But when vigorous growth took place in the middle and later stage of individual development, the resultant effect was gibbosity of form. When, however, vigorous growth began early and continued throughout development, the bifurcation of the ribs continued to take place and great size was attained, as in the Oriskany forms.

To generalize this theory of their growth, it may be said that the characteristic elements of plasticity, which at the Pentamerus stage were confined to early stages of individual development, became conspicuous and dominated the growth of relatively later and later stages of development with the passage of time. This accords with the general trend of hypothesis advanced by Hyatt.

Another series of rhynchonellas is represented by three fairly well-differentiated species described or referred to by Billings under the names *R. aspasia* and "*R.* like *bialveata*" Hall; and another form referred to under the description of the former in likening the species *R. aspasia* to *R. altiplicata* and *R. acutiplicata* Hall, and called "old specimens."

In the present collection the larger forms of this series described by Billings as *R. aspasia* ("7 by 6 lines in size") are not in evidence, but one of the smaller forms shows the characters corresponding to the description given rather than to the figures on the plate.

The two species in the present collection, with several well-marked specimens each, are referable to *R. aspasia* Billings and *R. bialveata* Hall. These belong, further, to a group of species of the Delthyris Shaly limestone in New York, including also the species *R. altiplicata*, *R. transversa*, *R. rudis*, and in the Lower Pentamerus the form evidently referred to by Hall as "*R. semiplicata* Conrad." Possibly *R. formosa* and *R. sulciplicata* Hall also belong to the series.

The specimens from the Maine fauna here referred to *R. aspasia* Billings (and, judging from the descriptions, the series of species described from New York by Hall may be included) are marked by their triangular form, with rather distinct narrow beaks, straight sides, few angular plications, a well-developed fold, and sinus at the front of the shell reaching halfway to beak. The shells are, in general, rather thin, and more or less flat along the middle part of the surface.

The description of *R. aspasia* by Billings seems to cover two forms, while the figure[1] in the descriptive paper applies to the typical form only. The following statement is referred to: "In old specimens, about twelve ribs on each valve, of which there are two or three in the sinus and three or four in the fold," and later the less angular rounded form of the sides of "old specimens."

The association of these "old" and larger specimens with the smaller typical forms brings in the characters which by Hall are made to distinguish other species, such as *R. rudis*, *R. transversa*, and apparently some of those referred to *R. formosa* on the plates. Resemblance to *R. acutiplicata* Hall is evident in the larger of the specimens in the collection.

Billings's figure well represents the typical characteristics of the larger of the specimens referred to this species; another of our speci-

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[1] Pl. III, fig. 6.

mens is well represented by Hall's figs. 6 *a*, *b*, and *c* of Pl. XXXIV,[1] which by Hall are referred to Conrad's species *R. semiplicata?*. One of the specimens has the smooth condition of surface near the beak described by Conrad as characteristic of *R. semiplicata*, but examination of our specimens makes it evident that this is here due to exfoliation, and that specimens, when well preserved, have evident plications as near to the beak as they can be distinguished for smallness of size. Fig. 3 of Pl. XXXV well represents another specimen. This is called "young of *R. formosa*" by Hall.

The forms described and figured by Billings as *R. aspasia*, excluding those he regarded as old specimens, should be taken as the type of his species. This will leave out certain forms, of as small size as the others, in which the sinus has two or three, and the fold three or four, plications. This latter form the writer takes to be a simple variety, but as it is a distinct form it confuses the definition of Billings's species to leave it among the other small forms, since only old specimens were supposed to have this character by Billings, whereas study of the specimens makes it evident that from the earliest stage of growth at which the surface plications are visible to the front of the shells no increase in number of plications occurs in any of this group of rhynchonellas.

The use of Billings's name, although the same forms were previously recognized and figured by Hall, may be defended on the ground that Billings clearly distinguished, defined, and figured the diagnostic characters of the form, while Hall distributed the same form under more than one species and confused it with others of different form. Having thus recognized Billings's species *R. aspasia* and its typical characteristics, it should be noticed that there are specimens in the Square Lake fauna presenting the variant characters represented by Hall's figs. 12, 14*b*, of Pl. XXXIV, referred by Hall to *R. transversa?*, but differing from 6 *a*, *b*, *c*, of the same plate by the possession of two more plications in the fold and in the sinus, the plications on the side being finer and more distinct. The writer has recognized this as *R. transversa* Hall, selecting as typical, from the several forms included by Hall under that name, one which seems to constitute the median combination of characters. It would be altogether improbable that any two paleontologists would distribute the original specimens figured by Hall under the names *R. inutilis*, *R. transversa*, *R. rudis*, *R. plano-convexa*, *R. sulciplicata*, and the Delthyris Shaly limestone specimens of *R. formosa* in the same groups under which they are originally described, or under any groups that would be described as specifically distinct by another person. By this remark it is not intended to express the opinion that there may not be distinct specific groups developed among the forms described under these names, but certainly it is

[1] Pal. New York, Vol. III.

difficult to form, from a study of the figures and descriptions, a clear notion of what particular combination of characters the author had in mind when sorting out and labeling the figures and applying specific names to them.

The specimens referred to by Billings as "like *R. bialveata*" are represented in the collection and evidently belong to this species. At least one of the specimens agrees fairly well with Hall's description, though the figures are poor and do not convey a correct idea of the true form and characters. The plications and the boundary plications of the sinus and fold are very sharp and distinct, even close up to the beak region. The two plications of the fold of the dorsal valve begin very close up to the beak, but they are depressed below the surface in a groove, and as they run out toward the front they come up even with the surface about midway and constitute a prominent fold at the front. This constitutes a well-differentiated specific group in the Square Lake fauna, the individuals of which evidently were naturally small. The narrow form, the abrupt sides, the sharply angular plications, and the mode of development of fold and sinus are dissimilar to the young stages of the other rhynchonellas of the fauna. These two species, *R. aspasia* and *R. bialveata*, correlate the fauna with the Delthyris Shaly limestone stage of the Lower Helderberg.

Applying this method of determining the stages of evolution of a series to the correlation of the Square Lake fauna, the results point to a stage of mutation corresponding to that of the Delthyris Shaly limestone of New York, but not in its full expression. The Square Lake forms are nearer to the Lower Pentamerus than to the Upper Pentamerus stage. This is indicated by the fact that the dominant form, named *R. mainensis* by Billings,[1] is nearer to *R. abrupta* of the Delthyris Shaly limestone series than to the side forms *R. ventricosa* and *R. nobilis*, which are the dominant types of the Upper Pentamerus. In plications and form the Square Lake forms are thus nearer the *R. mutabilis* stage of evolution. The state of mutation may be expressed by saying that the mature stage of *R. mutabilis* dominates the first half of the development of *R. mainensis*, whereas it dominates but a quarter of the *R. abrupta* form; and in the second half of growth of *R. mainensis* we have represented the three-quarters adult growth of *R. abrupta*. The result, in form, is a greater convexity of the beak part, with broadening of the median area, whereas the dominant characteristic of *R. abrupta* is the square-built form of the main body, with only moderately gibbous umbonal region. The gibbous form of the Delthyris Shaly limestone, *R. nucleolata*, shows its advance upon *R. mutabilis* by its fewer ribs at a corresponding stage of growth and size, and, when compared with *R. mutabilis*, shows an acceleration of the lateral superficial over the forward growth.

[1] See Pl. II, figs. 11, 14, 17, which is the typical form of *R mainensis* Bill., and Pl. I, figs. 9-24, and Pl. II, figs. 2, 5, 8, 11, 14, 17.

These species are taken as they are defined, without attempt to pass judgment as to the propriety of drawing the specific lines as they are represented. The attempt to closely correlate the specimens with some particular species diverts the attention from the evolutional laws which the evidence contains and illustrates.

In the above discussion attention is directed to the variations and the differences which are expressed in the dominant characters, or what might be called the habit or fashion characteristic of the whole group of rhynchonellas living at each successive stage. And it is the study of these peculiarities in the prevailing characteristics of a group of forms whose likeness suggests genetic affinity that promises to give us the means of detecting, in the fossils themselves, their position in the evolution of the race.

For this purpose, of course, it is necessary to have before us a sufficiently full representation of the group of species to show what are the dominant species of the fauna.

This study of a single group of species has demonstrated the fact that the evolutional stage of the group is indicated with precision, independent of the names of species, and independent of the fact that the specimens actually present in the Maine fauna agree precisely in scarcely a single case with those of any fauna of New York.

From this study it is evident that the Square Lake fauna is taxonomically the equivalent of the Delthyris Shaly limestone fauna of New York. The other species in the fauna bear out the same conclusion, both by the absence of species of lower and higher stages and by the presence of characteristic forms. The habit of the species of this group of rhynchonellids also suggests closer relationship to stages earlier than the Delthyris Shaly limestone of the New York section than to later stages.

The satisfaction attained by this method of correlation is the excuse for presenting it in this imperfect manner at the present time. Its elaboration and full presentation is reserved for future publication.

CHAPMAN SANDSTONE.

Presque Isle Brook.—The typical exposure of the Chapman sandstone is along the east (right) bank of the south branch of Presque Isle Brook, about a mile from the south line of Chapman Township and about a mile west of Tweedy's, on the road running southwest from Presque Isle.

The fossils and the locality were first brought to the writer's notice by Olaf O. Nylander, of Caribou, from whom the fossils were purchased for the Survey. In 1897 the locality was visited by the writer. More fossils were collected, and the character of the formation was observed. The station number is 1099 A. The rocks are mainly thick-bedded sandstones, with some shaly layers, and are exposed for a quarter mile

or so along the bank of the stream. The general direction of the dip is northwest—N. from 30° to 45° W. It was estimated that the thickness of the deposits in sight is at least 500 feet. The fossils are in the more shaly and thinner-bedded layers near the top of the exposure, between heavy-bedded sandstones, which in some cases show traces of plants, but generally are barren. Fossils occur in the more arenaceous beds, as is shown by their discovery in loose blocks in the neighborhood, but such fossiliferous sandstones were not discovered in place.

Fauna of 1099 A.

1. Rensselæria (Beachia) n. sp. cf. B. suessana.
2. Holopea cf. Danai.
3. Loxonema cf. planogyrata.
4. Pleurodictyum sp.
5. Spirifer gaspensis.
6. Orthonota n. sp. (cf. undulata).
7. Palæoneilo cf. constricta.
8. Palæoneilo cf. plana.
9. Palæoneilo cf. maxima.
10. Palæoneilo, five or six new species.
11. Sanguinolites n. sp. (cf. clavulus).
12. Leiopteria, six species.
13. Pterinea rectangularis cf. flabellum.
14. Pterinea, three species.
15. Cf. Glyptodesma sp.
16. Cypricardella cf. gregarius.
17. Nucula (n. sp.).
18. Beyrichia tuberculata Klöden.
19. Psilophyton princeps.
20. Stem large plant.

Edmunds Hill.—In the northern part of Chapman Township, just south of the northern boundary, the Chapman sandstone is exposed in the lower part of Edmunds Hill (1099 C). The whole base of the hill appears to be of sandstone and the cap is of igneous rock. The sandstone at this point is brownish to gray in color, from very fine to medium grained, and from shaly, thin layers to massive and thick bedded. Some of the same species are found at this and the more southern locality, while some species collected at Edmunds Hill have not been seen elsewhere.

Fauna of 1099 C.

1. Rensselæria (Beachia) n. sp. cf. B. suessana.
2. Spirifer arrectus cf. "cyclopterus" Billings.
3. Spirifer cf. concinnus.
4. Homalonotus cf. vanuxemi.
5. Chonetes nova-scotica Hall (cf. sarcinulatus var. plana Schnur).
6. Chonetes canadensis Bill. (cf. leptæna lata Sow.).
7. Bellerophon, two species.
8. Holopea sp.
9. Several gastropods.
10. Avicula cf. textilis.
11. Lamellebranchs, several genera and species.
12. Orthoceras, a fragment.
13. Tentaculites.
14. Beyrichia tuberculata Klöden.
15. Plant fragments.

Presque Isle and Mars Hill.—In addition to the above, several loose blocks were found along the roads in Presque Isle and Chapman, and one at the foot of Mars Hill, which have been marked 1099 B 1, 2, 3, 4, and 5. These contain the following species:

Fauna of 1099 B 1, 2, 3, 4, and 5.

1. Rensselæria (Beachia) n. sp. cf. suessana.
2. Spirifer raricostus Billings.
3. Spirifers of the arrectus and gaspensis form.
4. Avicula cf. securiformis.
5. Chonetes canadensis.
6. Bellerophon.

This fauna indicates a horizon nearly equivalent to the early stage of the Gaspé sandstone, which the Canadian geologists have correlated with the Oriskany. It is undoubtedly Eodevonian, and differs from the typical, more western, Oriskany fauna in the general facies of the species.

The abundant and great development of the *Rensselæria* is a notable feature of the fauna. The specimens are provisionally referred to *R. suessana*, which they most nearly approach among the American forms in generic characters. Comparisons with the figures of *Terebratula strigiceps*, referred by Keyser and others to Rensselæria, as well as study of the faunal associates, lead the writer to the opinion that the Maine specimens may be identical with the European form. The name *Rensselæria mainensis* is provisionally proposed for this form.

This species is not reported from the Lower Helderberg, and is, so far as the reports of its range are known, indicative of the Lower Oriskany. As is noted in the account of the Moose River sandstone fauna, this same species occurs in western Maine. The association of species there found corresponds more closely with the fauna of No. 8 of the Gaspé limestone series of the Canadian reports. The spirifers common are the forms called by Billings *Spirifera raricosta* and *Spirifera cycloptera*. This Moose River sandstone fauna, as stated on page 88, has been called Oriskany by Hitchcock, and the corresponding fauna of Limestone No. 8 and of the base of the sandstone of the Gaspé series is also called Oriskany by Billings.

Both these faunas and the Chapman sandstone faunas belong more nearly with the Lower Oriskany of Becraft and the southern Appalachians than with the fully developed Oriskany fauna of New York.

After the manuscript of this bulletin was finished and handed in to the Survey the author continued his investigation of the Chapman sandstone fauna, with the result of determining its correlation with the ("Tilestone") Downtonian fauna of the Welsh standard Silurian. The importance of this identification to a correct understanding of the Maine Paleozoics furnishes sufficient reason for the insertion at this place of the more significant parts of the paper in which the results were first announced.[1]

The identification of the Chapman sandstone fauna of Aroostook County, Maine, with the typical Ludlow "Tilestone" fauna of Mur-

[1] The Silurian-Devonian boundary in North America; I, The Chapman Sandstone fauna: by Henry S. Williams: Am. Jour. Sci., March, 1900, 4th series, Vol. IX, pp. 203–213.

chison furnishes important new evidence bearing upon the question of the exact boundary between the Silurian and Devonian systems in North America.

The discussion of the Hercynian problem has resulted in the placing, by several of the best continental European paleontologists, of the Silurian-Devonian boundary below the Hercynian fauna. Kayser,[1] followed by others, has adopted the opinion that the American equivalent of the Hercynian fauna is to be found in the Lower Helderberg.

Dr. J. B. Clark and Mr. Schuchert[2] have attempted to prove, on paleontologic grounds, that the Lower Helderberg fauna has a Devonian "aspect," and, trusting to their theories, have proposed to classify the formations containing the typical Lower Helderberg faunas in the Devonian system.[3]

When Professor Kayser's paper first appeared the writer was struck with the force of his paleontologic argument for classifying the Lower Helderberg and Hercynian faunas together, but was not then satisfied with the proof of the Devonian age of all the faunas so classified. When Dr. Barrois's paper on the Erbray faunas appeared,[4] it was gratifying to find confirmation of this opinion.

Dr. Freck's papers[5] were also emphatic in claiming a Devonian age for the Hercynian, and the combined evidence of these gentlemen (and others taking part in the discussion) pointed very strongly to the conclusion that we must drop our Silurian-Devonian boundary below the main part of the Lower Helderberg if we would adopt European (continental) usage.

The similarity of the Gaspé section to the typical Welsh sections of the Silurian system, running up to the base of the Old Red sandstone, gave me hopes that a study of the sections in northern Maine might reveal some faunas representing the upper part of the Silurian more closely than do the faunas of New York. As the fossils of Maine were studied a transition fauna was found which throws considerable light upon the exact position of the boundary plane between the two systems, Silurian and Devonian, in our North American rocks.

The fauna referred to is in the Chapman sandstone. A preliminary examination of it has revealed its close correlation with the Ludlow Tilestone fauna of Murchison, and its still closer relation to the Upper

[1] Die Fauna der ältesten Devon-Ablagerungen des Harzes: Abhand. geol. Specialkarte Preussen, etc., Vol. II, Pt. IV, 1878, pp. 284–285.

[2] The nomenclature of the New York series of geological formations: Science, Dec. 15. 1899, new series, Vol. X, pp. 874–878.

[3] See paper read at the Geol. Soc. America, Washington, December, 1899.

[4] Fauna du Calcaire D'Erbray, by Charles Barrois: Mém. de la Soc. géol. du Nord, Vol. III, April, 1889.

[5] Ueber das rheinische Unterdevon und die Stellung des "Hercyn," by Fritz Freck: Zeitschr. Deutsch. geol. Gesell., Jahrg. 1889, pp. 175–287, etc.

Arisaig fauna, D of Honeyman's section, which was "unhesitatingly referred to the Ludlow Tilestone" by Salter in 1862.[1]

This Chapman sandstone fauna is the latest marine Paleozoic fauna so far recognized in Maine, unless the Moose River fauna with Oriskany species be a little later. It is contained in a massive brown sandstone and argillaceous layers stratified therewith. Its comparison with other faunas links it with the so-called Oriskany of the Moose River region farther west, and also with the early beds of the Gaspé sandstone farther east. For this general region it is a representative of the transition zone from calcareous formations, which are unmistakably Lower Helderberg in age, up to coarse gray and red sandstones containing Devonian plants, reported to be 7,000 feet thick on the Gaspé Peninsula and to represent the Old Red sandstone phase of the Devonian system.

The fauna contains some twenty-five or thirty good species, a few of which can be identified with species of the Tilestone and Upper Arisaig faunas already described. A few Gaspé species described by Billings are closely approached; but, as a fauna, the resemblance to the typical Tilestone species of Murchison's Silurian system is most striking and suggestive.

The faunas, 1099 A, B, and C, are given on previous pages (see pp. 79, 80).

The significance of the correlation of this Chapman sandstone with the Tilestone of Murchison is found in the fact that the Tilestone contains the topmost fauna of the original Silurian system of Murchison. This fauna was described by Sowerby in The Silurian System (1839), and afterwards the Tilestone was placed by Murchison himself in the Silurian (Siluria, 1854). This change was brought about by the recognition by Murchison that paleontologic evidence is of greater importance in the determination of the age of rocks than petrographic evidence. By the study of The Silurian System it is perfectly evident that the Silurian system was intended by Murchison to include all the fossiliferous formations lying below the Old Red sandstone. We find this indicated clearly on pages 3 and 4, and still more clearly expressed on page 7, of the introduction of The Silurian System, where are found the following words (referring to the name Silurian): "The term was no sooner proposed than sanctioned by geologists, both at home and abroad, as involving no theory, and as simply expressing the fact that in the 'Silurian region' a complete succession of fossiliferous strata is interpolated between the Old Red sandstone and the oldest slaty rocks." We find that the reason for including the Tilestones in the Old Red was the fact that the soil weathered out reddish in the same way as the Old Red sandstone did where it was typically represented. These tilestones, however, were not always red in them-

[1] Quart. Jour. Geol. Soc., Vol. XX, 1864, p. 334.

selves; but, on passing below, the typical Upper Ludlow weathered gray. This seems to have been the prime reason in the mind of Murchison for classing the Tilestone with the Old Red. When, however, the first edition of Siluria was written, the fact that the species of this fauna were marine and not fresh-water types, and that some of them were identical with species in the formation below (which he called Silurian), led Murchison to call this Tilestone the top member of the Silurian instead of the bottom of the Old Red. In Siluria appears a concise description of the transition from the Ludlow rocks into the Old Red sandstone, as seen in Carmarthenshire and Pembrokeshire: "In all these places strata of dull greenish-gray argillaceous sandstone, minutely micaceous, differing chiefly from the type of the Ludlow of Shropshire in being harder and thicker bedded, and which repose on rocks with Upper Silurian fossils, plunge under red and green strata (the red rab of Pembroke), or bottom beds of the Old Red sandstone" (p. 141).

The typical localities from which the Tilestone fossils came are Felindre, on the Teme, and Horeb Chapel, in the valley of Cwm Dwr, between Trecastle and Llandovery, near Cwm Dwr. In The Silurian System the passage beds near Felindre are described as "hard, greenish, and reddish, highly micaceous sandstone, which contain the *Leptæna lata* and the *Terebratula nucula* of the Ludlow rock, together with casts of several shells identical with those found in the tilestones of the Cwm Dwr, Carmarthenshire, and which have never been found in the Silurian system below its junction with the Old Red sandstone" (p. 191).

The reason for placing the base of the Old Red sandstone above these tilestones is stated in the following passage in Siluria: "Even then, however, the fossils which were figured as characteristic of such tilestones exhibited little else, as I showed, than species common to the Ludlow rock itself. This zoological fact, and subsequent researches in other parts of England, above all those of Professor Sedgwick in Westmoreland, where the Upper Ludlow strata are much developed, have for eleven years led me to classify these tilestones with the Silurian rocks, of which they form the natural summit. For, even in their range from Shropshire through Hereford and Radnorshire, into Brecon and Carmarthenshire, whether they are of red or yellow colors, they are charged with *Orthoceras bullatum*, *Chonetes* (*Leptæna*) *lata*, *Spirifer elevatus*, *Orthis lunata*, *Rhynchonella nucula*, *Cucullella ovata*, *Bellerophon trilobatus*, *B. expansus*, *Trochus helicites*, *Holopella* (*Turritella*) *obsoleta*, and the minute bivalved crustacean, *Beyrichia tuberculata*. All of these are the most common fossils of the Upper Ludlow rock; although a few of them descend as low as the Caradoc sandstone" (p. 139).

From these quotations it is evident that the Tilestone was regarded by Murchison as the upper member of the Silurian system as he defined it in 1854 and as it occurred in his typical sections.

The writer's attention was first attracted to the possible equivalency of the Chapman sandstone and Tilestone of Murchison (= Downton sandstone and Ledbury shale) by noting that *Leptæna lata* of the list in The Silurian System is a true chonetes and closely resembles some of the specimens from Chapman. On studying up the definitions and synonymy of the species, it became evident that Davidson, who identified *Leptæna lata* von Buch with *Chonetes striatella* Dalman, in doing so was following DeKoninck. In quoting synonymy, however, he excludes Sowerby's fig. 13 of Pl. V, which, as figured, presents the flatness characteristic of the species occurring in the Chapman sandstone.

The chonetes (No. M 248) of the Chapman sandstone agree with Hall's *C. nova-scotica* [1] in size and form, and from descriptions it seems that the small specimens referred to *C. canadensis* by Billings,[2] having the proportions of *C. melonica*, are identical with Hall's species *C. nova-scotica*. There is also a specimen (No. M 250) (the writer originally referred it to Orthothetes, the hinge and beak being absent) which upon examination is found to present the typical characters of *Chonetes canadensis* Bill., so far as they are visible. Dawson states that "the new species *Chonetes nova-scotica* is very characteristic of the upper member" [of the Arisaig section].[3] Hall compared the species with "*C. cornuta* of the Clinton group of New York,"[4] but the Clinton species is much smaller than even the smallest specimens in the Chapman sandstone. Billings, in describing the chonetes of the Gaspé series, calls his more gibbous form *Chonetes melonica*, and he compares this with *C. striatella* of Dalman, but finds it distinct (p. 16). *Chonetes canadensis* Billings differs from the description of *C. melonica* in being nearly flat. Billings remarks, however, "Small specimens of this species [*C. canadensis*] have nearly the proportion of *C. melonica*, but are always nearly flat, while those of the latter are always more convex" (p. 18).[2] From a study of the descriptions it is evident that these "small specimens," referred by Billings to his species *C. canadensis*, are identical with the form described by Hall as *C. nova-scotica*, thus linking together the chonetes of the transition beds of the Gaspé section, formation D of the Upper Arisaig of Nova Scotia, and the Chapman sandstone.

Although the writer finds no description of the specimens referred by Sowerby to the species *Leptæna lata* von Buch, the figure so labeled on Pl. V certainly appears as if nearly flat. Even were this not the case (which an examination of the type specimens would demonstrate), the fact that we have in the Gaspé series both fully gibbous and flat forms,

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[1] Canadian Nat. and Geol., Vol. V, p. 144, fig. 2.

[2] Palæozoic Fossils, Vol. II, Pt. I, p. 18.

[3] Canadian Nat. and Geol., Vol. V, p. 137.

[4] Op. cit., p. 145.

which closely resemble each other in other respects, gives reason for supposing that the British form is at least represented by these Gaspé and Maine species.

In Hall's description of the Arisaig specimens of *Chonetes nova-scotica* it is stated: "A stronger and more elevated stria often marks the median line from beak to base of the ventral valve."[1] This feature is seen on several of the specimens of the Chapman sandstone, and, curiously, it is not always the central plication. In one case several plications, a little out of the center, are thus enlarged. Such a trick of variation would seem distinctly to indicate close phylogenetic relationship.

In the Oriskany of Albany and Schoharie counties, in New York, a form (*C. complanatus*) quite as large as Billings's *C. canadensis* is described by Hall. The larger forms are all from the Gaspé, Maine, and Oriskany faunas at the summit of the Silurian. *Leptæna lata*, which is figured as larger than the ordinary types of Chonetes, is said to be "one of the most characteristic shells of the Upper Ludlow."[2]

The bellerophons furnish a second set of diagnostic species. In the original list of the Tilestone fauna four species of Bellerophon are named, viz, *Bellerophon carinatus*, *B. striatus*, *B. trilobatus*, *B. globatus*.

Bellerophon trilobatus is said to be a characteristic form of the Tilestone.[3] This species is represented in both the Chapman sandstone and formation D of Arisaig. In Siluria it is stated that "*B. expansus*, *B. Murchisonæ*, *B. carinatus*, and *B. trilobatus*, generally of small size, are most abundant everywhere in the upper beds of the Ludlow rock" (p. 231). *Bellerophon carinatus* and *B. trilobatus* are both represented in the Chapman; and Honeyman reports all four species from the Upper Arisaig, Zone D.[4]

A third diagnostic form is called "*Agnostus tuberculatus* (*Battus tuberculatus* Klöden)" by Sowerby in 1839.[5] This is *Beyrichia tuberculata* Klöden. Several specimens of this species, or a very closely related form, are recognized in the Chapman fauna. Hall described, under the name *Beyrichia pustulosa*, a species from Zone D of the Arisaig, of which he says: "This species resembles very nearly the *B. tuberculata* of Klöden, as described and figured by Mr. T. Rupert Jones."[6] Of this form Murchison writes, in Siluria, as follows: "Of the latter genus the Upper Silurian species is *B. tuberculata*. It is very abundant from the Wenlock shale to the highest Ludlow

[1] Descriptions of new species of fossils from the Silurian rocks of Nova Scotia, by James Hall: Canadian Nat. and Geol., Vol. V, p. 145.

[2] Silurian System, p. 603.

[3] Op. cit., p. 141.

[4] Quart. Jour. Geol. Soc., Vol. XX, p. 343.

[5] Silurian System, p. 604, Pl. III, fig. 17.

[6] See Jones's identification of this species in the Arisaig rocks, in Quart. Jour. Geol. Soc., Vol. XXVI, p. 492.

stratum, and is a good index of Upper Silurian rocks, though found sometimes in the upper division of the Caradoc" (p. 236).

In addition to these characteristic species of the Tilestone fauna in the Maine and Arisaig rocks, a majority of the forms described in Sowerby's original list of that fauna are represented by the same, or closely allied forms, in both the Chapman sandstone and Zone D (Honeyman), Arisaig, as will appear from the following table:

List of representative species of the Tilestone fauna in the Chapman sandstone, Maine, and Zone D, Arisaig, Nova Scotia.

Tilestone.	Chapman Sandstone.	Zone D, Arisaig.
1. Cypricardia cymbæformis	Goniophora cf. Hamiltoniæ	C. cymbæformis, cf. Nuculites (Orthonota) carinata Hall
2. Pullastra lævis	Cypricardella cf. gregarius	not reported
3. Cucullæa antiqua 4. C. ovata 5. C. cawdori	Palæoneilo cf. cuneatus P. cf. concentricus P. cf. elongatus P. cf. nuculiformis P cf. subovatus and others.	Cleidophorus cuneatus C. concentricus C. erectus C. elongatus C. semiradiatus C. nuculiformis C. subovatus
6. Arca —— ?	?	?
7. Avicula rectangularis	Pterinea rectangularis	?cf. Avicula Honeymani
8. Leptæna lata	Chonetes nova scotica C. canadensis	C. nova-scotica H. C. tenuistriata
9. Spirifer ptychodes (=S. elevata Dalman)	Sp. arrectus var. Sp. concinnus Sp. cyclopterus Bill. Sp. raricosta Bill.	Sp. rugæcostus Sp. subsulcatus
10. Orthis lunata	?	?
11. Terebratula nucula (=Rhynchonella)	not seen	Rhynchonella (3 species)
12. Lingula cornea	not seen	Lingula sp.
13. Natica glaucinoides	?	?
14. Trochus helicites	Pleurotomaria sp. (M 227)	?
15. Turbo Williamsi	Holopea cf. Danai	?
16. Turritella obsoleta	?	Murchisonia Arisaigensis
17. T. gregaria	Loxonema cf. planogyrata	?
18. T. conica	?	M. aciculata
19. Orthoceras semipartitum 20. O. ? 21. O. striatum 22. O. tracheale	A single fragment	O. punctostriatum O. nummulara Sow. O. ibex Sow. O. exornatum
23. Bellerophon carinatus	B. carinatus	B. carinatus
24. B. striatus	?	B. striatus
25. B. trilobatus	B. trilobatus	B. trilobatus
26. B. globatus	?	B. globatus
27. Tentaculites scalaris?	B. cf. elongatus	T. distans.
28. Battus tuberculatus	Beyrichia tubercalta	B. pustulosa Hall B. equilatera

In addition to the above, *Homalonotus knightii* König is reported from the Upper Ludlow, and also from Zone D, Arisaig; and an undetermined representative of the same genus appears among the Chapman specimens.

The presence of plants is further significant. In the Chapman sandstone a specimen of Psilophyton, which is probably *P. princeps*, appears in the midst of the marine fossils, giving evidence of proximity of land, and also of the transition condition leading up to the Old Red sandstone type of Devonian. "Psilophyton (?)" is also reported from the Upper Arisaig,[1] and it is the "Tilestone" of Wales (=Upper Ludlow and Downton sandstone) in which the earliest known traces of land plants appear in the Welsh succession.[2]

The above evidence leads directly to the conclusion that the fauna of the Chapman sandstone of Maine is the equivalent of the Tilestone fauna of Wales and of the uppermost Arisaig fauna of Nova Scotia. The latter has already been authentically identified with the "Ludlow Tilestone" by Salter, and the general fauna of the Upper Arisaig has been identified with the Lower Helderberg by all those who have studied the species.

The Nictaux iron-ore fossils indicate a somewhat younger fauna, which has been recognized by Dawson and other paleontologists as approximately equivalent to the Oriskany sandstone of the New York section.

In the Gaspé series the place of transition from the Gaspé limestones to the sandstones is very near to the horizon of the Oriskany sandstone farther west. The stratigraphic and petrographic evidence in the Maine series points to the equivalency of the Chapman sandstone with the base of the Gaspé sandstone. The particular fauna of the Chapman sandstone is not known, at present, in the Gaspé series. But if this correlation with the Gaspé series be correct, the relations of the several known faunas of the Maine series are in complete harmony with the known succession of the Gaspé faunas, and with such an interpretation. In that case the Square Lake fauna of Maine would be equivalent to the fauna of the upper limestones in the Gaspé limestone series, and thus correspond with the known sequence of faunas in the Arisaig series.

Reviewing the whole evidence, the Chapman fauna must be regarded as the equivalent of the topmost fauna of the typical Welch Silurian system (= Upper Ludlow, Tilestone of Murchison, or Downton and Ledbury formations of later authors). This places the Silurian-Devonian boundary for North America where it was determined to be by De Verneuil in 1847,[3] classifying the Lower Helderberg formation

[1] Ami, Catalogue of Silurian fossils from Arisaig, Nova Scotia: Nova Scotia Inst. Sci., 2d series, Vol. I, 1892, p. 185.

[2] H. B. Woodward, The Geology of England and Wales, 1887, pp. 104, 105.

[3] Note sur le parallélisme des dépots paléozoiques de l'Amérique septentrionale avec ceux de l'Europe: Bull. Soc. géol. de France, 2d series, Vol. IV.

in the Silurian system. The special Chapman fauna, the writer is at present inclined to think, is equivalent to the Lower Oriskany fauna, as recognized at Becrafts, and farther south in Virginia and Tennessee; but however the precise correlation with the faunas of interior America may be settled, the place of the Chapman fauna above the general Lower Helderberg fauna is well established by the Gaspé and Arisaig sections.

NEW HAVEN, CONN., *December, 1899.*

MAPLETON SANDSTONE.

This sandstone contains plant remains which have been submitted to Mr. David White, of the United States Geological Survey, for special study. *Psilophyton princeps* is among the species seen, and the age of the sandstone is clearly Devonian. Psilophyton was also seen in the Chapman sandstones, with a marine fauna. These Mapleton sandstones are believed to be of more recent age than the Chapman rocks, but were probably continuous with them, and the two may represent the base and succeeding strata of the Gaspé sandstone of Gaspé Peninsula.

Dr. Gregory has given an account, in his part of this report, of the petrographic, structural, and areal features of this sandstone (p. 136).

MOOSE RIVER SANDSTONE.

In Somerset County, northwestern Maine, there is a belt of sandstones and arenaceous shales, in some zones of which there is a fairly abundant fauna.

It is generally a tough, grayish sandstone with some argillaceous layers, weathering brownish from iron oxides, and of considerable thickness, running up into the hundreds and probably reaching several thousands of feet in thickness.

It was called "Oriskany sandstone," by C. H. Hitchcock, in the Report on the Agriculture and Geology of Maine,[1] and was described in the following terms: "Its most southwest locality is at Parlin Pond, then it is seen on Moosehead Lake, Chesuncook Lake, Telos and Webster lakes, and the Aroostook River."[2] It is mapped as a belt, about the width of a township, extending from the fourth township west of Moosehead Lake, on the seventh range (Bradstreet), thence running obliquely northeastward in a somewhat curving line toward Ashland, in Aroostook County. Billings, in the proceedings of the Portland Society,[3] defined the fauna at two points near Telos Lake.

In 1889 a series of collections from the region west of Moosehead Lake was made by Gilbert Van Ingen for the purpose of ascertaining

[1] Agric. and Geol. of Maine, 2d series, 1861, p. 379; Geology of wild lands, map opposite p. 377.
[2] Op. cit., p. 379.
[3] Proc. Portland Soc. Nat. Hist., Vol. I, 1869, Pt. II, p. 106.

the precise nature of the fauna. The collections so made were from the following localities:

Parlin Pond, Somerset County.—1059 C is a section beginning on Parlin Stream at the middle dam, where the stream runs for over a mile through sandstones and shales. Numerous fossils were obtained at various horizons in this section, marked C 1–12, and from loose bowlders, marked C w, x, y, and z.

As this and the next section contain a typical representation of the fauna, the detail of the rock sections is herewith given:

Section 1059 C.

	Feet.
C 26. Bluish sandstone with quartz veins, barren	25
25. White sandstone, soft, friable, barren	6
24. Blue sandstone with ? jasper ? pebbles, thinly laminated, barren	1
23. White sandstone, soft, friable, barren	½
22. Blue sandstone, barren	100
21. Shaly sandstone, barren	6
20. Fossiliferous shaly sandstone	½
19. Blue, very hard sandstone, barren	6
18. Fossiliferous sandstone	1
17. Bluish, very hard sandstone, barren	36
16. Thick bedded, barren	4
15. Thick bedded, fossils	7
14. Fossils	½
13. Barren	13
12. Barren	8
11. Shaly, very soft	1
10. Barren	?
9. Barren	135
8. Fossils	7
7. Shaly	½
6. Barren	2
5. Fossiliferous sandstone	1
4. Barren	6
3. Fossils	2
2. Barren	7
1. Thin-bedded sandstone, fossils	24

Fauna of 1059 C.

C 20. Spirifer arrectus.
C 7. 1. Discina cf. Crania bella.
2. Psilophyton.
3. Plant fragments.
C 6. 1. Lissopleura æquivalvis.
2. Plant stem.
C 1–3. Spirifer cf. cyclopterus.
C 1–3. Stropheodonta blainvillii Bill.

The fuller faunas were obtained from loose blocks, more or less weathered, apparently from the neighboring ledges, viz: C^w, C^x, C^y, C^z.

Fauna of 1059 C^w.

1. Loxonema.
2. Stropheodonta cf. perplana.
3. Avicula.
4. Spirifer cyclopterus Billings.
5. Leptocœlia flabellites.
6. Lissopleura æquivavis.
7. Cf. Conostrophia complanata.

Fauna of 1059 C^x.

1. Lissopleura.

Fauna of 1059 C^y.

1. Strophomena blainvillii Bill.
2. Chonostrophia complanata.
3. Nucula.
4. Cf. Orthothetes.
5. Cf. Cryptonella eximia.
6. Loxonema.
7. Cf. Platyceras.

Fauna of 1059 C^z.

1. Spirifer arrectus cf. cyclopterus Bill.
2. Leptocœlia flabellites.

Jackman farm.—1059 D is a section on Canada road, in the town of Jackman, 10 miles south of Moose River settlement and 5 miles north of Parlin Pond.

Bean Brook.—1059 D 1 is a section on the east side of the Canada road, at Bean Brook, 3 miles north of Parlin Pond Hotel. A massive bed of sandstone of unknown thickness with fossils on some layers; the rock is very tough and gray in color; dip 18°, N. 70° E.

D x. A sandstone bowlder, with Orthoceratites.
D 2. Blue sandy shale, many fossils; dip 20°, N. 70° E.
D y. A bowlder with corals common.
D 3. Lowest outcrop of shale, fossils common.
D 4. Shale on farm, few fossils; dip 15°, N. 70 E.

Fauna of 1059 D 1.

1. Lissopleura æquivalis.
2. Tentaculites.
3. Tentaculites cf. elongatus.
4. Cf. Modiomorpha.

Fauna of 1059 D 2.

1. Dalmanites anchiops.

Fauna of 1059 D 9.

1. Leptocœlia flabellites.

Long Pond.—1060 A, ledges at northwest end of Long Pond, forming islands in the lake:

		Feet.
A 1.	Hard fissile shale, unfossiliferous, dip NW .... about	50
A 2.	The same rock, 200 yards northeast of A 1	10
A 3.	The same rock, 300 yards north of A 1	25
A 4.	Ledge on north shore, Hugh Redmond's farm, called by the lumberman "The Joe ledge," about one-fourth mile southeast of No. 3; dip 55°, N. 20° W .... about	375

1060 B 4.—A ledge on the south shore, 5½ miles west of outlet; dip 70°, S. 20° E., thickness 40 feet; thin layers contain fossils, otherwise barren sandstone.

Fauna of 1060 B 4.

1. Strophomena blainvillii Bill.
2. Cf. Megalanteris ovalis.
3. Avicula.

Little Brassua Lake.—Section 1061 A is on the south shore of Little Brassua Lake, along the line of the Canadian Pacific Railroad. The section begins at the milepost 237 and extends south about three-fourths of a mile along the track eastward. This station is in Sandwich Township, west of Big Brassua Lake.

Section 1061 A.

		Feet.
A 0.	A heavy-bedded sandstone, barren, thickness unknown.	
A 1.	120 feet east of A 0, barren, bluish gray on new surface, but weathers to gray	15
A 2.	Hard blue compact sandstone, weathering to whitish; dip 43°, N. 10° W., barren	15
A 3.	1,230 feet directly ESE. of A 2; more shaly than A 2; dip 62°, N. 10° W.; 28 feet from its lower surface fossils were found	60
A 4.	1,140 feet east of nearer end of A 3; a hard, heavy-bedded sandstone, blue, weathering to gray	6
A 5.	A bluish-brown, shaly sandstone, containing fossils	8
A 6.	Hard sandstone, with round vertical borings	8
A 7.	Heavier-bedded sandstone, light blue-gray, barren	13
A 8.	Slaty, dark surfaces, laminated, barren	12
A 9.	Blue-gray sandstone, like A 7, few fossils	12
A 10.	Blue, laminated, shaly sandstone, barren, like A 8	5
A 11.	Hard bluish gray, like A 9, barren	50
A 12.	Laminated shaly sandstone, with fossils	10
	Drift	30
A 13.	Hard, heavy-bedded sandstone, barren	10

Fauna of 1061 A 4.

Chonetes antiope Bill.

Fauna of 1061 A 5.

1. Lingula sp.?
2. Sphenotus sp.
3. Modiomorpha sp. (also 1061 A 3).
4. Lingula artemis.

Stony Brook.—Section 1061 B 1 is a hard, tough sandstone, shaly in some places, the greater number of the fossils being from the shaly part.

Fauna of 1061 B 1.

1. Spirifer gaspensis.
2. Spirifer gaspensis, large.
3. Chonetes antiopa Bill.
4. Chonetes cf. mucronata.
5. Strophomena blainvillii Bill.
6. Orthis cf. Lucia Bill.
7. Leptocœlia flabellites (? to this fauna).
8. Spirifer ?
9. Avicula.
10. ? Crinoid.
11. Zaphrentis cf. rugulata.
12. Amphegenia sp.
13. Loxonema sp.
14. Dalmanites sp.
15. Modiomorpha sp.
16. Spirifer cycloptera? Bill. pl. 3 A, fig. 4 c.

Big Brassua Lake.—Several exposures were examined on the shores and islands of Big Brassua Lake (1062). The rocks presented the same general characters met in the sections farther west.

Section 1062 A.

A. On west shore of lake, commencing with A 1, a low ledge on first point, about one-half mile from inlet (Moose River).
A 1. A rather solid shale, with very fine fossils; dip 25°, S. 80° E.

Brassua Stream.—The following is a section at Brassua Stream:

Section 1062 B.

B 1. A ledge under water, about 2 miles above the lake.
B 2. A ledge of shaly sandstone, forming a fall in stream, about 2½ miles above the lake; dip 28°, N. 10° W. Two fossils (?) were found in it.
B 3. The same rock, with same dip, exposed for 100 yards upstream.
B 4. Same rocks, same dip, 1,000 yards farther (above B 3).
B 5. Same, 200 feet farther.
B 6. Same rock, same dip, 300 feet farther. One fossil.
B 7. 200 feet farther the same rock is exposed, but contains very many fossils.
B 8. 150 feet farther, same rock, with a few fossils.
B 9. 250 feet farther, same rock, no fossils.
B 10. 200 feet farther, same rock, no fossils; dip 57°, N. 10° W.

Fossils were obtained from the following strata:

Fauna of 1062 A 1.

1. Sp. cyclopterus (H) Bill.
2. Chonetes antiopa Bill.

Fauna of 1062 B 2.

1. Orthothetes deformis.
2. Plant stem, (B 3).
3. ? two lamellibranchs (? B 2).

Fauna of 1062 B 6.

1. Orthothetes deformis H.

Fauna of 1062 B 7.

1. Beachia suessana.
2. Orthothetes deformis.
3. Strophomena blainvillii.
4. Platyceras sp.

From 1062 C 3.

Plant stems.

CONTRIBUTIONS TO THE GEOLOGY OF MAINE

Part II. GEOLOGY OF THE AROOSTOOK VOLCANIC AREA

INCLUDING AN ACCOUNT OF THE CLASTIC ROCKS OF AROOSTOOK COUNTY

BY

HERBERT E. GREGORY

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CONTRIBUTIONS TO THE GEOLOGY OF MAINE.

PART II. GEOLOGY OF THE AROOSTOOK VOLCANIC AREA.

By Herbert E. Gregory.

CHAPTER I.

INTRODUCTION.

GEOGRAPHY.

The area considered in the present paper includes the section of Maine known as the "Aroostook country." An examination of the map, fig. 1 (p. 12), shows its location in the extreme northeast extension of United States territory.

The region is without natural boundaries, and hence for purposes of this report the area is outlined and bounded as follows: On the east by New Brunswick; on the north by the St. John River and the Fish River Lakes; on the west by a line joining Portage Lake, Ashland, and Oakfield, and on the south by a line from Oakfield to Houlton. These lines include an area about 75 miles long by about 30 miles wide, which is separated from other parts of Maine by a belt of forest land, whose monotony is broken here and there by a few rich farms. The natural connection is with New Brunswick, and there is nothing in the topography or the character of the soil or the people to indicate when the boundary line has been passed. Much of the Aroostook country has been settled from the Maritime Provinces, and until a very few years ago the outlet for produce and the main line of travel was along the St. John River to the city of St. John, on the Bay of Fundy. The construction of the Bangor and Aroostook Railroad has largely changed this condition of affairs, but the region still reminds one of an agricultural island of great richness, reached from the southern part of Maine after traversing an uninhabited expanse of forest land.

The most thickly settled portion of northern Maine is the eastern border from Houlton north along the belt of slated limestones (Aroostook limestones). In the vicinity of Houlton this strip is hardly more

than 6 miles wide, but 30 miles farther north, in the valley of the Aroostook River, it widens to over 20 miles, and includes the prosperous townships of Fort Fairfield, Presque Isle, Mapleton, and part of Castle Hill, on the south side of the river, and Caribou, Woodland, and New Sweden on the north side. Farther up the Aroostook, about Ashland, is a limited amount of exceptionally fertile land.

The amount of settled country, however, is but a small part of northern Maine. West and north of Ashland there is a stretch of unbroken forest extending nearly to the St. Lawrence River, visited only by hunters and lumbermen, who use the rivers and lakes as highways. Within the area described in this report there are some twenty townships with no sign of human habitation except the winter log roads and occasional lumber camps. The change from well-cultivated fields to an uninhabited expanse of forest, "burnt land," and swamp is sudden and complete, as is well seen by ascending the highest points of the region. The pathless woods, with their soil thickly covered with products of forest decay, make the geologic investigation difficult, and render detailed mapping of extended sections impossible.

PREVIOUS EXPLORATION.

Geologic work in northern Maine has been carried on in the past by geologists employed by the State or by the Dominion of Canada. The first State survey was undertaken while yet the Aroostook lands belonged jointly to Maine and Massachusetts, and had in view the exploration of these lands preparatory to opening them to settlement. This first survey (now generally known as the Jackson survey) was instituted by an act of the State legislature passed on the 21st of March, 1836.[1] During the year 1836 a general topographic survey of the immediate vicinity of Houlton and of the St. John River from Woodstock to the mouth of the Madawaska was completed. In the following year Dr. Jackson, accompanied by Mr. Hodge, made the descent of the Aroostook River from La Pompique Stream to the St. John. The more important outcrops were located and briefly described, and the occurrence of iron ore in what is now Wade Plantation was dwelt upon at considerable length.[2] Exploration was not attempted except along the river. This report was written for the prospective settlers, and consequently the information as to trees, soils, and water supply is more complete and more valuable than the strictly geologic matter. The third and final annual report[3] of the Jackson

[1] Five thousand dollars was appropriated and Dr. Charles T. Jackson was placed in charge. Associated with him in the first year's work were Dr. T. Purrington, as agent on the part of Maine, and James T. Hodge, who represented Massachusetts. The survey was continued for three years, with different assistants and smaller appropriations each year.

[2] Second Ann. Rept. on the Geology of the Public Lands belonging to the two States of Maine and Massachusetts, Augusta, Maine, 1838.

[3] Augusta, 1839.

survey was transmitted to the legislature by Governor Fairfield on February 13, 1839. Besides the record of the work accomplished during the year 1839, this report contains a general summary of the results obtained by the survey during the three years of its existence. Considering the lack of accurate maps and the difficulties of travel, the work accomplished by Dr. Jackson was of a high order. It is to be regretted that all the specimens so carefully collected and labeled have disappeared, with the exception of the set presented to Bowdoin College.[1]

Twenty-three years elapsed before the State undertook further geologic work. In 1861 a "scientific survey" of the State was organized.[2] Professor Hitchcock was appointed geologist and gave some portion of his time to investigations in the Aroostook Valley. In the Geology of the Wild Lands[3] he describes a section from Charlotte to Presque Isle and one from Penobscot Bay to Ashland. In the same volume Mr. Packard gives an account of his exploration of the Fish River Lakes, and of the route from Portage Lake through Ashland to Presque Isle. He also announced the discovery of the Square Lake fossil locality. During 1862 Dr. Holmes traversed the settled parts of Aroostook County, but added no geologic information of importance. While the work was in this preliminary stage the legislature saw fit to cut off the appropriation, and the work which had been begun so well and which promised so much to science was brought to a close.

These two reports of Professor Hitchcock include what is known generally of the geology of Maine. The features occurring along the main traveled routes are briefly described, and the age and areal distribution of the different rock formations are worked out and represented upon a geologic map. The amount of work done in 1861 and 1862 with so small an appropriation was highly creditable, and was so well done that the general interpretations then made are likely to stand the test of time. The permanent value of the second State survey would be greatly enhanced if the entire collection of minerals, rocks, and soils so carefully made had been preserved.[4]

In 1885 Professor Hitchcock published a summary description of the geology of Maine, with a map in colors.[5] Some changes from the map

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[1] Bayley and King: Catalog of the Maine Geological Collection, with a Brief Outline History of the two Surveys of the State, Waterville, Maine, 1890.

[2] The scientific staff was Ezekiel Holmes, naturalist; Charles H. Hitchcock, geologist; George L. Goodale, botanist; J. C. Houghton, mineralogist; A. S. Packard, jr., entomologist; C. B. Fuller, marine zoologist.

[3] Bound with Agriculture and Geology of Maine, 2d series, 1861.

[4] Unfortunately the typical collection deposited in the statehouse was removed from its place and the specimens carelessly thrown into boxes, their labels often going into other boxes. As a result of Prof. W. S. Bayley's efforts, the remnant of this collection is now under the care of Colby University, at Waterville, Maine. The specimens have been identified as far as possible by the description given in Jackson's reports, and a catalogue has been published (Bayley and King, footnote 1).

[5] Geology of Northern New England, p. 1.

of 1861 were rendered necessary by new data furnished by the New Hampshire and New Brunswick surveys. This is the only complete geologic map of Maine that has been published.

As explained elsewhere, there is an intimate connection between the geology of Maine and that of New Brunswick and Quebec, and accordingly the investigations in the Canadian provinces have thrown considerable light on geologic problems in Maine. On the other hand, many facts are better exhibited in Maine, and the New Brunswick survey has found it advisable to conduct some field operations along the Aroostook River and the Fish River Lakes.[1] Prof. L. W. Bailey has had many years' experience in dealing with the complicated problem presented by the New Brunswick formations, and has given the benefit of this experience in his discussion of the similar geologic conditions of Maine.

The above-mentioned papers comprise all the material directly relating to the geology of northeast Maine. Much more work has been done on the coast line and many contributions of value have been made, especially in regard to the surface geology and the petrography of those parts which have been mapped.[2] At present the relation between the geology of southern and northern Maine has not been determined, and these parts of the State must be treated as two distinct areas.

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[1] The results of these excursions are given in the Transactions of the Royal Society of Canada and in the Reports of the Geological Survey of Canada. Three papers in particular, from the pen of Prof. L. W. Bailey, are of great value for the interpretation of the stratigraphy of the region, viz:

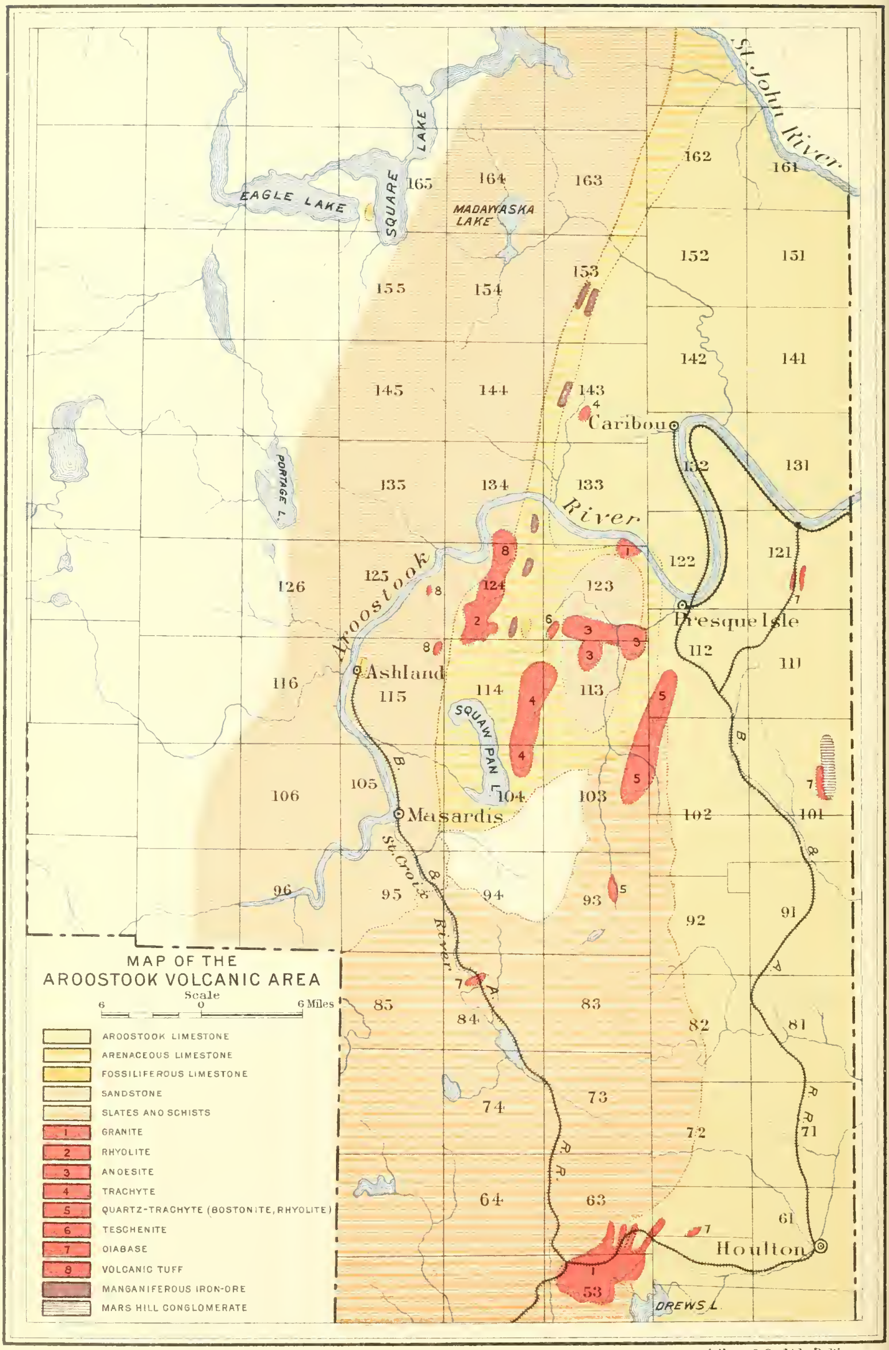
On the Silurian system of northern Maine, New Brunswick and Quebec: Trans. Roy. Soc. Canada, Vol. IV, 1887, Sec. IV, pp. 35–41.

Notes on the physiography and geology of Aroostook County, Maine: Trans. Roy. Soc. Canada, Vol. V, 1888, Sec. IV, pp. 39–44.

On some relations between the geology of eastern Maine and New Brunswick: Trans. Roy. Soc. Canada, Vol. VII, 1890, Sec. IV, pp. 57–68.

The substance of these papers may be found also in Reports of Geological Survey, Canada, 1886–1893.

[2] The papers of recent years, especially those of Shaler, Davis, Crosby, Stone, Dodge and Beecher, Kemp, Bayley, and Smith are especially valuable.



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CHAPTER II.

IGNEOUS ROCKS.

Northeastern Maine is essentially a region of sedimentary rocks, among which igneous outcrops occur to a relatively small extent. The most numerous exposures of igneous rocks are located in Castle Hill and Mapleton townships, where they form the prominent topographic features (see map, Pl. IV). Even here, however, their extent is quite limited. It is an interesting fact that, although the distribution is so limited, the number of well-defined igneous types is large and shows wide variation in character.

It is the purpose of this chapter to discuss the general structure, nature, and field relations of the igneous rocks of this region, and to leave the microscopic and chemical descriptions to the succeeding chapter. A third chapter will briefly treat of the general petrographic questions presented by a study of this area.

The igneous rocks occurring in northeastern Maine will be described under the following heads: Granites, Rhyolites, Trachytes, Andesites, Diabase, Teschenites.

GRANITES.

Granite occurs in two small areas within the region described in this report. One is in the northeast corner of Mapleton Township, near the Aroostook River; the other is near Drews Lake. Neither exposure is topographically conspicuous, and it is not surprising that one of them has heretofore escaped notice. From the general character of the region a wider distribution of granite rocks was to be expected.

MAPLETON GRANITE.

The Mapleton granite (locally known as Munson's granite) forms part of a low, rounded hill, which has suffered so much erosion that no sharply defined ledges remain. The top of the hill is a tablelike mass covering some 6 or 7 acres, and bounded on the east, where it nears the calcareous slates, by a low cliff. The north side gives the best outcrops, and the slope is covered with slabs of granite which have been loosened above by the frost. The rocks on the west and south sides of the hill are completely obscured by products of forest decay. The granite, as shown by its outcrops, forms an oblong mass, with northeast-southwest axis, about 1 mile long and one-fourth mile wide. It has probably a somewhat greater extent, however, as shown by the fact that where the sedimentaries first appear to the west—about one-eighth

mile distant—the contact metamorphism indicates nearness to the igneous mass.

The granite itself is not uniform in appearance. In parts of the field it is almost black; in others it is of a light color. The dark and the light areas are not confined to any particular locality, and the transition from one to the other may occur within a few inches or may be imperceptible for rods. The light parts may contain areas and streams of the dark, or the dark parts be smeared and banded with the light, without any apparent regularity as to size or shape. It is similar to the appearance produced by the presence of dark aggregates in granites, but is on a larger scale.

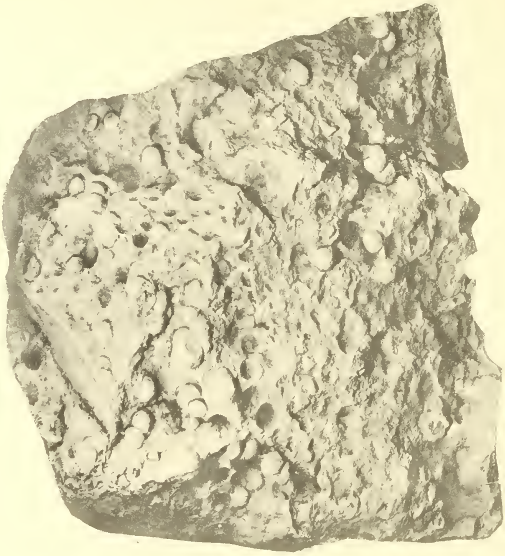
The field relations indicate that this is an intruded mass. No contact was seen, but the sedimentary rocks near by are metamorphosed in proportion as they approach the granite. There are no lavas or other extrusive materials found within miles of this outcrop, although they are abundant in the region. The granite is a small area surrounded by sedimentary rocks, and seems to have been recently uncovered by the great general denudation which northern Maine has suffered.

In the bed of the Aroostook River, at the base of the granite hill, are dikes of aplite, syenite, and kersantite, which vary in width from a few inches to 500 feet. They have been intruded between the sedimentary strata, which are altered in consequence. As to their origin and time of formation, these dike rocks are referred to the granite mass.

DREWS LAKE GRANITE.

The granite of Drews Lake forms a somewhat conspicuous feature of the landscape. The country here is a low, rolling, wooded plain with many swamps, and the granite constitutes part of a group of hills and low knobs standing out in contrast to the general level. In the depressions between the hills is a group of lakes which constitute the head waters of branches of the Mattawamkeag, which flows southwesterly to the Penobscot, and of the Meduxnekeag, which empties into the St. John. The shores and bottoms of these lakes—this whole region, in fact, is strewn with large, angular, granite bowlders. The eminences here are in some cases granite; in others, highly metamorphosed schists and altered slates. The schists seem to be remnants of the ancient surface rocks, which in part have been wholly worn away, but in places still cover the granites. The granite hills are generally rounded, but in places present craggy, jagged profiles. Hitchcock[1] has mentioned this area and roughly outlined it on his geologic map. He considers it, together with several exposures to the southwest, to be part of one large mass typically exposed at Island Falls. This relationship is not indicated by the mass under discussion, which is not large and is nearly

[1] Agriculture and Geology of Maine, 1862, p. 360.



(A)

(B)

(A) SPHERULITIC RHYOLITE.
(B) VESICULAR LAVA.

everywhere flanked by altered sedimentaries. The contact metamorphism and the relative position of the surrounding rocks are evidence that here, as in Mapleton, we have a locally intruded mass.

Dikes of aplite and granite-porphyry connected with the main mass are well exposed in the railroad cuts at the north base of the hilly district. Some are minute streaks; some are 40 to 50 feet wide. They are seldom straight and with even borders for any distance, but branch and fork, or even form a rude network. These dikes exhibit some interesting features which will be considered under another heading.

This granite is a valuable resource for Aroostook County, and the quarry opened a few years ago at Ludlow is already furnishing considerable stone, especially for engineering purposes.

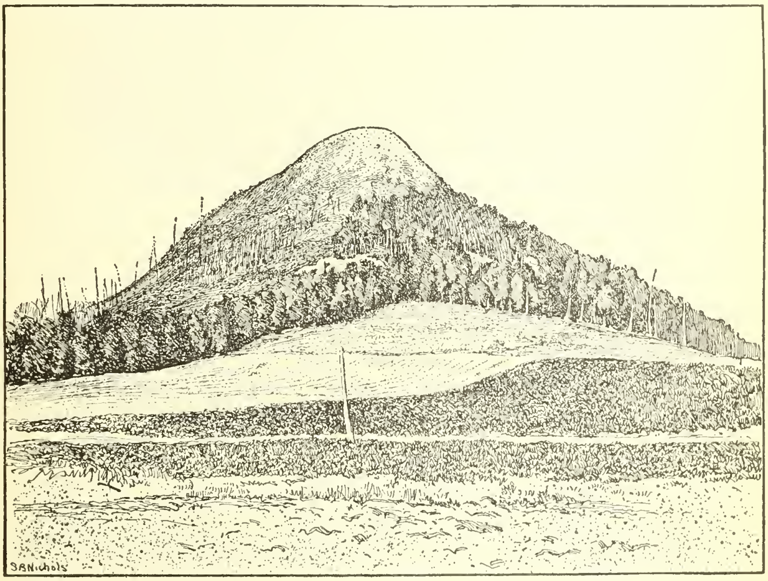


FIG. 2.—View of Haystack Mountain; looking northwest.

RHYOLITES.

HAYSTACK RHYOLITE.

There is a prominent ridge of land extending north and south through the center of Castle Hill Township from the Aroostook River to near the head of Squawpan Lake. The State road crosses it a little to the west of the Castle Hill Hotel, and the Haystack road crosses it at the Halfway House. This ridge is formed of extrusive volcanic material, the north end being formed of the andesites grouped about Castle Hill and the south end of the rhyolites which have Haystack as their center. This mountain is the most prominent topographic feature of the Presque Isle-Ashland area, in which it is unique as to form and position (see fig. 2). It rises abruptly from the general plain to a height of about

600 feet, with an average slope of about 50°. The last 100 feet is very steep, and the whole appearance leads one to recognize the appropriateness of the name by which it has long been known. The base of the main mass covers scarcely more than one-fourth of a square mile, but connected directly with it is a narrow ridge of the same volcanic material extending about three-fourths of a mile to the northwest. The easiest ascent is on the north side, where, on account of the connected ridge, the slope is scarcely over 30° until the top is neared. The east and the west sides are very precipitous. The talus on the slopes is abundant and is, in general, made up of small angular fragments, although on the west side there is a confused mass of giant blocks so piled as to leave large, roomy spaces between and underneath, which are locally called caves. Higher on the slope these detached pieces are more and more in place, until near the top blocks weighing 40 tons and more are found separated from the main mass by deep cracks a few inches wide and are ready to be pried off by the frosts of winter. The top of the hill is an uneven surface covering less than one-fourth of an acre, and an examination of the rock there exposed reveals the presence of a complicated system of intersecting cleavage cracks which has determined the form and size of the loose blocks on the slope. As one walks about the base of Haystack or climbs to the top, attention is attracted by the varied appearance of the materials composing the mass. On the top, only the dense bluish-white felsitic rock appears. Halfway down the slope the surface exposures have the peculiar birch-bark appearance which characterizes parts of the white rhyolite. At the southeast base of the hill occur little knobs which are formed of a dark breccia with jasperlike fragments embedded. Near by is the variety of rhyolite made up of little spherules; and finally, about one-half mile east of the hill, there is a well-marked vesicular lava. A detailed description of these various forms of rocks will be found in the chapter on petrography (pp. 146–186).

From the field relations alone it is no easy matter to determine the character of this igneous mass. Only the top part is free from trees, underbrush, and moss, which conceal the rocks and make traveling difficult. The talus covering is very deep and widespread, and the drift has been so deposited as to conceal the contacts. Consequently the exact relation between the igneous and sedimentary rocks is not known. There does not seem to be much metamorphism except in places to the east of the mountain. The character of the rocks, however, is conclusive, for they are undoubtedly flows of lava, and indicate by their amygdaloidal structure nearness to the surface of flow. The probable field relation is indicated diagrammatically by the accompanying cut (fig. 3).

The whole mass has either been formed by some very recent extrusion or is the remnant of more extensive flows which have been long

(A)

(B)

(A) "BIRCH BARK" WEATHERING OF RHYOLITE.
(B) TRANSVERSE SECTION.

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buried and only recently brought to light by denudation. This question will be discussed in connection with the geologic history of the region.

RHYOLITES OF THE HILLS ADJOINING HAYSTACK.

The rock forming the hills immediately north of Haystack is in general closely similar both in general aspect and in microscopic structure to that forming the main mass. The hill on lot 115 is composed of rock almost identical with Haystack in structure, but appears to have suffered some brecciation and occasionally contains fragments of foreign material. The rock forming Pyles Hill conforms well with the typical rhyolites, and, because of the amount contained in the hill and the unaltered condition, might well have been described as the type, with Haystack proper as an additional occurrence. About the center of the west line of lot 115 the rhyolite exposed is of a white or

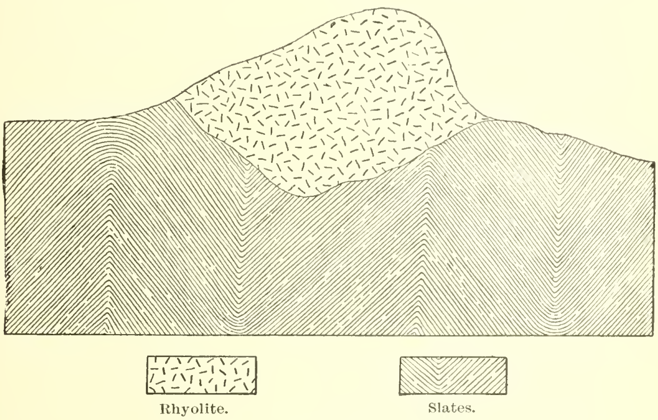


FIG. 3.—Diagram of Haystack Mountain.

flesh color, and a microscopic examination shows it to be a sort of transition form between the true rhyolites and the quartz-trachyte of Quoggy Joe Mountain. To the west of Haystack, along the branches of Welts Brook, the rhyolite rocks have been cleaved and broken and afterwards recemented, so as to present the appearance of a coarse breccia. In one place along the south line of lot 100 an extensive exposure of coarse volcanic ash was discovered, which will be described on page 127. A careful determination of the details of the rock formation about Haystack is impossible until land is cleared and the swamps are drained.

TRACHYTES.

Trachytes were found in three different localities in Aroostook County. One mass constitutes Hedgehog Mountain, another is found in Chapman Township, and a third area of doubtful trachytes forms low hills along a branch of the Caribou Stream in Woodland Township.

HEDGEHOG TRACHYTE.

Hedgehog Mountain is probably the largest single mountain mass in eastern Aroostook County. It is a ridge extending some 4 to 5 miles in a northeast-southwest direction and rising about 1,000 feet above the stream beds at its base. It is surrounded by lakes and swamps, except on the northeast, in which direction it extends for a mile or two as a flat-topped hill. The mountain is thickly overgrown with trees and brush, and this, together with the great depth of the talus, makes an examination of the structure and rock formation impossible except at the very highest points, where the cliffs are exposed, and the continual splitting off of the blocks on the east and west sides of the mountain has left a bare, jagged ridge, in places scarcely 100 feet wide. The whole mass is separated into great blocks by two prominent cleavage planes, one of which strikes N. 80° W., the other N. 20° E. The blocks themselves in the ledge and on the talus slope suggest an indurated feldspathic lava. When the region about this mountain can be more fully explored interesting relationships will doubtless be brought out, but at present it is advisable to limit the discussion to a description of the occurrence and character of the rock composing the mass.

CHAPMAN TRACHYTE.

The Chapman trachyte occurs in the northwest corner of the township, on the north-south road near the west township line, where outcrops were seen on a hill about 1 mile south of the Presque Isle River. All the region south, east, and west of the river is forest and swamp land, with the exception of a few cleared farms along the road. It is on one of these farms that the trachyte occurs, close by the house and in the adjoining field. The outcrop occurs as rough ledges and jointed tabular rocks, rising but a few feet above the general level of the field, and in all cases is quite limited in extent. The several exposures seen indicate an area of about 5 acres, but it is likely that further examination, especially after the land is cleared, will show that the mass covers several square miles and may be connected with the little-known Hedgehog Mountain to the west. At present, however, the swamps and products of forest decay effectually conceal the rocks, and nothing more definite can be said as to its relations to the other formations of the region.

WOODLAND TRACHYTE.

The outcrops of trachyte at this locality have been too little studied to warrant an extended description.

QUARTZ-TRACHYTES.

Quartz-trachyte will be described from two localities in the region included in this report. It forms the group of hills west of Fort Fair-

field Junction called Quoggy Joe, and it also occurs as a dike outcropping on the south branch of the Presque Isle River about the middle of T. 9, R. 3.

QUOGGY JOE QUARTZ-TRACHYTE.

Quoggy Joe is the prominent member of a group of hills with outlying knobs that form part of the divide between the Presque Isle and Meduxnekeag rivers. The ridge extends several miles in a northeast-southwest direction. Beginning on the north with low knobs, it rises to a height of 300 to 400 feet above the general level at Quoggy Joe and continues as Green Mountain into the unexplored region farther south. The hill as viewed from the east or west presents steep slopes from base to top, but the northeast side is easily ascended by following the ridge, difficult climbing being found only near the top. Angular blocks of light-colored rock varying in size from an inch to many feet in diameter cover the upper slopes. Wherever the rock is exposed on top of the hill it is cut by wide cleavage cracks which run continuously in the same direction (about northeast) for many feet. Less distinct cracks intersect these, so that the whole hill is seamed and fissured into giant blocks. So prominent and regular are these cleavages that the hill gives the impression of being a sedimentary mass. Quoggy Joe has a lake at its eastern base, and elsewhere is surrounded by swamps and forests, so that the limits of the igneous mass could not be traced. The trachyte extends less than a mile from the hill to the east, as shown by the occurrence of sedimentaries just beyond Quoggy Joe Lake.

QUARTZ-TRACHYTE OF TOWNSHIP 9, RANGE 3.

The second occurrence of quartz-trachyte is on the Presque Isle River and is a very inconspicuous exposure, seen only as a small ledge extending from the bank. The rock as it appears in the ledge is specked with shining quartz and is exceedingly tough. The heavy vegetation prevents a determination of the width and extent of the mass, and even prevents definite ascertainment whether it is a dike. The locality is difficult of access, owing to its distance from settlement and the lack of roads which can be used in the summer season.

ANDESITES.

Andesites are very rare rocks in eastern United States, but are the most abundant extrusives so far found in northern Maine. They form prominent hills and determine the general topography in some places, while in others they are represented by isolated remnants among the sedimentaries. The greater number of occurrences are of lava and breccia, but andesitic ash and tuff are also found well developed. In the following descriptions only the more important localities will be

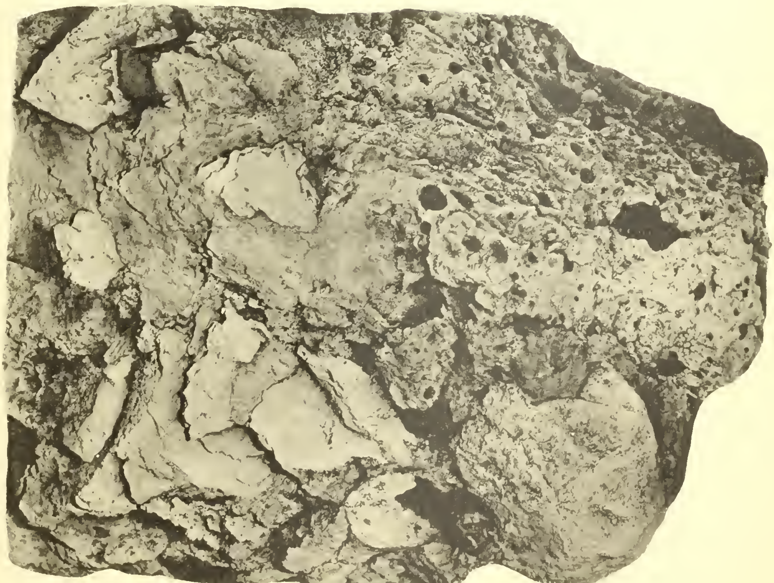
dealt with in detail; the less prominent outcrops will be spoken of in a general way. The andesites are located in the townships of Chapman, Mapleton, and Castle Hill, where they constitute the prominent ridges known as Edmunds Hill, Hobart Hill, and Castle Hill, besides less noticeable masses.

EDMUNDS HILL ANDESITES.

Edmunds Hill is situated in Chapman Township near the middle of the north township line, and is simply the highest part of a ridge running north-south for several miles. The hill itself rises some 200 feet above the road at its base, and presents the outline of a drumlin, so evenly has it been graded at each end. The trees, brush, talus, and glacial deposits entirely conceal the formations about the base of the hill, and it is only after climbing half the distance to the top that the bare rock is found in place. In climbing the west side of the hill, fragments of fossiliferous sandstone were found among the andesite blocks, and the sandstone ledge outcrops about 100 feet below the top. The thickness and extent of the sandstone could not be accurately determined, because it was covered in so many places with heavy blocks and small fragments of the igneous rock which had fallen from above. The contact was not seen. The entire top of the hill is of augite-andesite. The main mass is uniform in texture, and is cut into large blocks by cleavage cracks. When the blocks fall down the slope they remain as huge masses. The south and north ends, however, and part of the west side, are quite different. Here the rock is split up into long, thin slabs by a set of parallel cracks remarkably uniform in direction and length, which retain their parallelism even when the rock is folded or faulted. Cross cleavages intersect these cracks every few feet, so that when the rock is loosened it comes out in flat slaty pieces one-fourth inch or so in width and several inches, or even several feet, in area. The whole appearance is that of thin-bedded sedimentaries which have been folded and faulted (see Pl. III, *A*). The general direction of these cleavage planes is N. 30° E. on the north end and N. 35° E. on the south end, with a dip southeast at a high angle. The fault planes strike N. 70° E., and, besides cutting out the thin slabs at the ends of the hills, they occur all along the west side, each indicating a slight movement. It seems probable that the Edmunds Hill Ridge owes its origin, at least in part, to the formation of a fault block.

The outlying knobs and hills to the east of the main mass are also of andesite, usually microcrystalline, but sometimes porphyritic. The igneous rock does not extend far to the west, but is replaced by arenaceous slates, and while no precise boundaries of the formation were determined, the field relations suggest that the hill is the remnant of a lava flow over the eroded and upturned edges of sandy rocks of Ordovician age.

(A)



(B)

(A) ANDESITIC LAVA.
(B) ANDESITIC BRECCIA.

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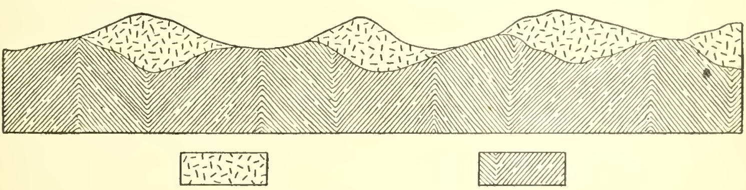
HOBART HILL ANDESITES.

This hill is an isolated mass of andesite forming a prominent feature in the landscape to the west of Presque Isle Village. It is situated partly in Mapleton Township and partly in Chapman Township, and is surrounded entirely by low, poorly drained swamps and forest lands. It is visited only for lumber and tan bark, which are secured in limited quantities during the winter season. The hill is about 1¼ miles long and three-fourths mile wide, and rises quite abruptly above the plain to a height of 300 feet as a single well-defined mass without branches or outliers (see Pl. III, *B*). The sides are everywhere steep, and in places present cliffs 40 to 50 feet high. The top is bare only where fire has recently destroyed the vegetation. The talus slopes present a confused mass of large and small blocks of andesite, which entirely conceal all outcrops except where cliffs are exposed. On the west and north sides numerous bowlders of red sandstone and conglomerate are piled along the slope and mingled with the volcanic material. These were traced to their parent ledges scarcely a half mile to the north, and the bowlders serve to cover the contact of the



Andesites. Slates.

FIG. 4.—Section on Mapleton-Presque Isle road.

andesite with the Mapleton sandstone. Specimens collected from various places on the hill show but slight differences in composition and texture, except the rock from the northwest corner, which is a breccia of andesitic fragments and seems to be situated along a fault line. Here, as at Edmunds Hill, no actual contact between formations was observed, but the sedimentaries were traced to the very base of the hill, and the facts indicate that the hill is a remnant of a lava flow.

SOUTH MAPLETON ANDESITES.

In addition to the prominent hills of andesite just mentioned, there are some ten or twelve less conspicuous outcrops in the fields in the southern part of Mapleton Township to the north and the south of the Mapleton-Presque Isle road. They usually occur as narrow ridges, and seem to be remnants of lava flows which once occupied former valleys, and are now left standing because of the erosion of the sedimentaries on both sides. The accompanying cut (fig. 4) illustrates the theoretical position of the andesite outcrops along the Mapleton-Presque Isle road.

CASTLE HILL ANDESITES.

Castle Hill is the local name for the northern end of the high, narrow ridge extending north-south across the township of that name. While not so conspicuous a feature as Haystack Mountain, at the southern end of the same ridge, it forms the most considerable prominence on the immediate bank of the Aroostook River, and as all the early travel lay along this stream, the ridge was an important landmark to the first settlers. There is no common local usage as to the limits of Castle Hill, and in this report the term will be applied to the masses of andesite and volcanic clastics which lie between Aroostook River and the State road from Ashland to Presque Isle. It covers an area 2½ miles long and varies in width from one-half to three-fourths of a mile. It is partly in Castle Hill Township and partly in Wade Plantation. The wagon road crosses the hill at the southern end, where it rises little higher than the surrounding plain. The east side has a gentle slope, and, being cut up into separate low knobs by small streams, the ridge effect is not apparent. The west side is formed by Welts Brook and the Aroostook River, which at this point is forced by it to take the abrupt backward turn so noticeable on the map. Calcareous and arenaceous slates are exposed in the bed of the river, while a short distance back steep slopes and cliffs of lava and ash rise to a height of several hundred feet. The hill is densely wooded and in places swampy, except at the southern end and along the east side. At these points the bare rocks are occasionally exposed and present great variation in character. In one place heavy ledges of gray andesite are exposed, particularly on the knobs occupying the northwest and southeast corners of lot 31. In the woods east of the mouth of Welts Brook is an outcrop of black silicified tuff between slates. On the southeast corner of the hill are loose ash beds containing fossils, coarse and fine volcanic breccias, and pumiceous lava in quite fresh condition. Where the old lavas have been planed off by glaciers and have been protected from weathering the outlines of bombs and pillows are plainly revealed. When weathered these bombs are loosened and drop out as oval or egg-shaped bodies with amygdaloidal surface and denser interior, and lie about thickly strewing the fields. In one place there is a cisternlike depression in the solid andesite some 10 feet deep and 30 feet in diameter, while close about it are piled a great number of very vesicular bombs and much glassy and brecciated ash. Its appearance suggests a small blowhole made by a single explosion. The striking fact about all the volcanic accumulations in the Castle Hill region is their freshness and their unistakable character.

DIABASE.

Typical diabases have not been found at all in northern Maine, and rocks of diabasic habit and near enough in chemical composition to be

classed as such are represented only by few outcrops, each of small extent. The most important exposure in the region is at Aroostook Falls, just over the international boundary line, in New Brunswick. Two small dikes of rock like that at Aroostook Falls were found crossing the east-west road about three-quarters of a mile northeast of Fairmount Station on the Bangor and Aroostook Railroad. The width of the dikes and their contact with the calcareous slates were not made out. Other diabase dikes of small extent are found at the southwest base of Mars Hill. Besides the above outcrops, which will be further described, rocks of diabasic character were noticed along the railroad 2 miles west of New Limerick, and a good example of a sheared diabasic rock was observed in a cut at milepost 140, a little south of Weeksboro Station on the Ashland branch of the Bangor and Aroostook Railroad.

AROOSTOOK FALLS DIABASE.

As noticed by previous writers,[1] this diabase occurs in a number of dikes cutting the blue limestone of the region, which at this place is closely folded and faulted along planes extending in more than one direction. The dikes are most abundant at the very foot of the falls, or series of rapids, where they have a uniform appearance and vary in size from mere dikelets 2 inches or more in width to a massive faulted and jointed dike 30 feet or more in width, which has affected the adjoining rocks in structure and texture. Most of the dikes trend N. 25° W., and dip W. $< 60 \pm$, which makes them run at about right angles to the general strike of the sedimentaries. The dikes in the rapids above the falls form a series of abutments, causing narrows where they cross the stream, but they are so easily eroded that in other places they project little, if any, above the limestone which they cut, and if the present channel had not been occupied by the stream in recent geologic times, the dikes would be an inconspicuous feature of the river. As it is, the dikes can not be traced beyond the present valley.

MARS HILL DIABASE.

This diabase occurs in two dikes of different types situated close together on the southwest flank of the mountain. Walking up the hill from the McPherson house in the direction of the bare ledge on the southern summit, one passes over calcareous slates and sandstones and comes to a dense blue-black rock, which appears to be a diabasic dike in direct contact with the slate conglomerate. As one climbs higher and over thick beds of arkose, another outcrop of igneous rock is seen at the base of a long talus slope. This is a second diabase dike, or perhaps a flow, of unknown width and extent, which attracts the atten-

[1] Jackson, Second Ann. Rept. Geol. Public Lands, 1838, p. 45. Hitchcock, Agriculture and Geology of Maine, 1861, p. 215. Bailey, Ann. Rept. Geol. Nat. Hist. Survey Canada, 1885, Pt. G., p. 22.

tion of any observer because of the chunks of bright-red jasper included in it. It is at present impossible to locate these dikes accurately or to trace their boundaries, for the entire mountain side is overgrown with dense underbrush, which has grown up after burning and cutting off the large trees, and which makes the discovery of outcrops a matter of chance. The other outcrops of diabase are easily found, and present no peculiarities in their method of occurrence.

TESCHENITES.

The massive dikes of this rock form the most conspicuous geologic feature of the southwest part of Mapleton Township (see fig. 5). Few continuous outcrops are seen, but the many small exposures

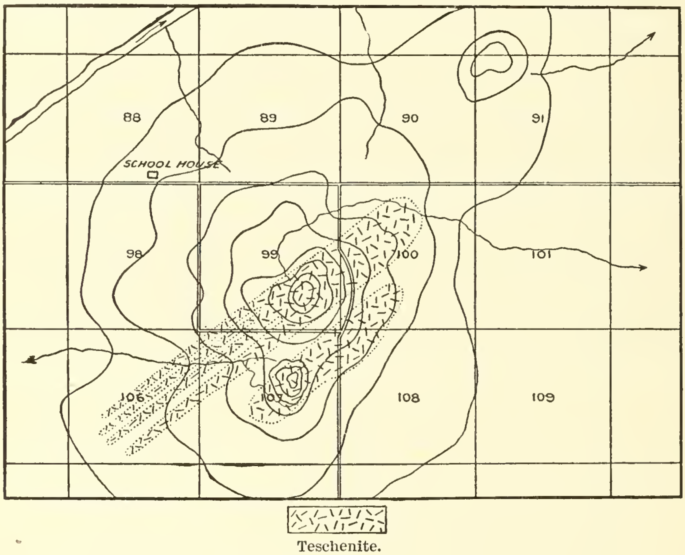


FIG. 5.—Map of part of Mapleton Township, showing teschenite area.

indicate a series of dikes in close proximity, extending about 1½ miles, with a combined width of dikes and intervening slates of three-fourths of a mile. The places most favorable for study are on lots 100 and 107, but lots 106 and 108 furnish good outcrops, and the southeast half of lot 99 is practically composed of a hill of this material. One mile east of Mapleton post-office a road leaves the section line and turns south, in order to avoid passing over a hill, and the blasting and digging required in cutting this road have given an excellent geologic section for a distance of about a quarter of a mile across the strike of the sedimentaries and the direction of the teschenite dikes. The exposures show the country rock in this vicinity to be an arenaceous shale baked, at the contact with the dike, into a gray siliceous slate. The dike itself outcrops along the road for 400 feet, with great variation in appearance. All these rocks have been well preserved by the

dense forest growth, and, when the moss and vegetable débris is removed, show their glacial grooving in a very fresh state. This large dike can not be traced to the east, but forms the hill immediately west of the road, and was found outcropping on lot 106, nearly a mile to the west. Forest and swamp prevented further exploration.

The large hill on lot 107 is another teschenite mass, which extends a half mile to the east and is terminated by two small knobs on lot 100. The ledges best exposed are on the northeast corner of the hill, where they present a ragged ridge about 200 feet wide, which probably indicates the dike. This dike is separated from the one first mentioned by the sandy slates of the region.

On lot 106 the field relations of the teschenite are seen to the best advantage, for here the land has been cleared and plowed and a section running for a long distance directly across the strike can be examined. Here the large dike traced from the east is seen to take on a rude columnar form at the contact, with columns perpendicular to the wall, and it is seen to be sheared in a direction rudely parallel with the slate bedding. Teschenite dikes and the slates alternate along the whole section. The dikes have black, dense border facies and coarse crystalline interiors, and contain many broken and hardened fragments of slates. The slates have a general strike N. 50° E. and dip SE. $<60°$, and are much folded and broken near the teschenites. In general the dikes follow the direction of the strike, but those taking other directions are also present.

Besides this Mapleton area the teschenite outcrops on the State road at the southwest base of Castle Hill, but the extent and character of its occurrence at that point have not been studied.

CHAPTER III.

CLASTIC ROCKS.

INTRODUCTION AND CLASSIFICATION.

In this chapter it is proposed to consider all rocks other than igneous which occur in the region covered by this report. Volcanic tuff, sandstones, limestones, and schists will be included in the description. All the material will be studied as varieties of rock, and from a lithologic point of view, without special regard to age or stratigraphic position. The pyroclastic rocks are treated of here rather than with the igneous rocks proper, because they are for the most part waterlaid, and are closely related to the sandstones and conglomerates of true sedimentary types.

In the scheme of classification which follows, the rocks have been divided into groups according to their composition as revealed in the hand specimen and by microscopic examination, precisely as if one were dealing with igneous rocks. The lines of demarcation have necessarily been somewhat arbitrarily drawn, for it was found that the tuff-sandstone-limestone series is complete and that all members of the group are united by transition forms. The table on page 19 will show the general divisions, while further details will be given in connection with each group as it is taken up for discussion.

The phyllites, schists, and manganiferous iron slates have been studied only in general, but are believed to belong to the same lithologic series and are accordingly assigned a place here.

Classification of the clastic rocks.

Rock.	Principal components.	Typical exposures.
Volcanic tuffs	Ash and lapilli (glassy)	Castle Hill tuff.
Volcanic sandstones and conglomerates.	Fragments of igneous rock.	Conglomerate on Welts Brook.
Sandstone and conglomerates.	1. Few fragments of igneous rock, quartz, feldspar.	Sheridan sandstone.[1]
	2. Quartz, feldspar, and fragments of sedimentary rock.	Chapman sandstone.
	3. Quartz and fragments of sedimentary rock.	Mars Hill conglomerate.
	4. Quartz, fragments of sedimentary rock, and calcite.	On Sheridan road.
	5. Quartz and (little) calcite.	In railroad cuts south of Masardis.
Calciferous sandstones	Calcite and quartz	New Sweden Township.
Arenaceous limestone	Calcite and (little) quartz	Gritty beds in Aroostook limestone.
Slated limestone	Calcite	Aroostook limestone.
White limestone	Calcite	Fossiliferous limestone at Ashland.
Slates and schists		Ashland Branch.
Manganiferous iron slates.		Wade Township.

[1] The general names applied to the sedimentary rocks in this paper were suggested by Professor Williams, and are further elaborated as to age and condition of formation in Part I of this bulletin.

VOLCANIC TUFFS.

Under this general heading will be included all the pyroclastic rocks of northeast Maine which contain lapilli and other original volcanic materials, and are thereby distinguished from volcanic conglomerates, which are composed principally of angular fragments of volcanic rocks.

FIELD DESCRIPTION.

The true volcanic tuffs are found on the southern half of the Castle Hill ridge, as outcrops in the road near the northeast corner of Ashland Township, and in several places on the Ashland-Sheridan road near the line separating these two townships.

CASTLE HILL TUFFS.

The most favorable place for the study of these rocks is in the open fields and along the roadside about one mile west of Castle Hill Hotel, where they are found well exposed, in close connection with the andesites, on lots 31 and 32 (see map, fig. 6).

Normal type.—While the southern Castle Hill tuffs differ considerably from one another in external and microscopic appearance, they are essentially alike and will be roughly classed together as the normal type.

The outcrops of this type occur as low knobs or swells of land, always quite limited in extent and never forming marked topographic features.

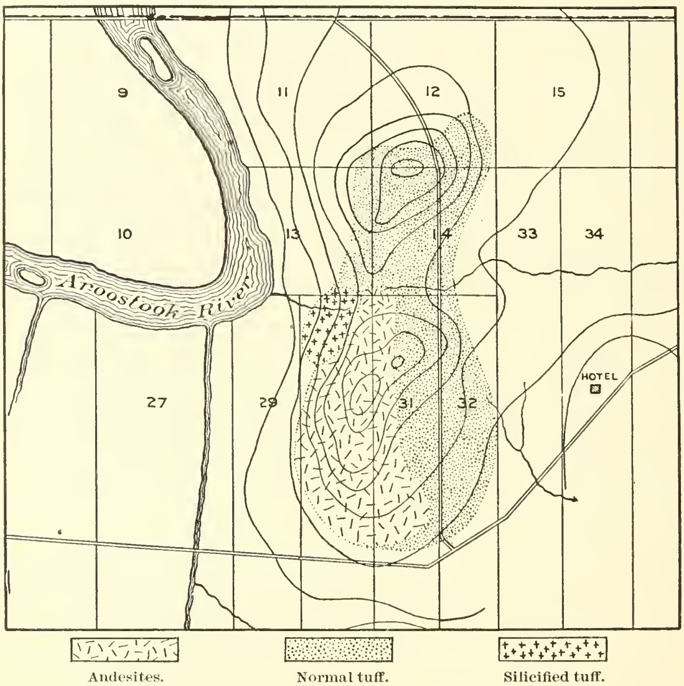


FIG. 6.—Map of Castle Hill area.

As might be expected in rocks of this class, the exposed surfaces show much alteration to a loose, porous rock, easily crumbled between the fingers and having the appearance of partly consolidated sand. Embedded in the tuff are many fragments of igneous rock, consisting mainly of rhyolite, vesicular andesite, and ashy or pumiceous fragments averaging about a quarter of an inch in longest diameter, but pieces are found as large as 6 by 10 inches. Corals and brachiopods are also found sparingly distributed in the coarser tuffs. On that part of the ridge known as Richardson Hill a conglomeratic facies is found in addition to the normal type.

All these tuffs are waterlaid and show an assortment of the coarser and finer materials into a rude stratification, as the rock is seen in the ledge, and loose bowlders from apparently the same outcrops show their bedding distinctly. Cleavage planes running toward the northeast cut the ash beds, and small faults and slickensided surfaces are commonly present. The embedded pebbles show results of strain, and occasionally are so cleaved and fractured that they drop into angular fragments when removed from their matrix.

Silicified type.—An exposure of a hard, black silicified tuff was found on the brow of a steep hill about one-eighth of a mile east of the mouth of Welts Brook. The rock is broken into huge cubes by cleavages in the ledge, and loose blocks are strewn over the slope. The density of the forest growth and the thick mat of vegetable débris prevented a detailed study of the structural relations of this outcrop.

The relation of these volcanic ash beds to the other rocks of this vicinity was not made out with certainty, on account of the small number of outcrops and the absence of exposed contacts. So far as worked out, however, the facts indicate that the tuffs are contemporaneous with the andesitic flows. The normal type of ash, the *aa* structure, and the andesitic lava and breccia all have their best development within a radius of a few hundred feet, and are believed to be near the original vent. The nearest sedimentaries are about an eighth of a mile distant on the east and somewhat nearer on the west, and wherever seen are clearly folded and occasionally baked. The present ash beds are considered as remnants of somewhat more extended beds which were laid down upon folded calcareous and arenaceous slates through which the volcanic vent had been drilled.

TUFF IN NORTHEAST PART OF ASHLAND TOWNSHIP.

The outcrop of volcanic tuff in this locality is on the north side of the lower Presque Isle–Ashland road, about 2½ miles west of Haystack Mountain, and is made up of ash in beds of differing aspect, together with an intrusion or flow of andesitic character. Part of the tuff appears in the field as porcelainlike material, while the most typical ashy variety presents surface characters much like coarse amygdaloidal lava, for which it has been mistaken.

TUFF ON THE ASHLAND-SHERIDAN ROAD.

The volcanic tuff exposed in the road near the boundary line between Ashland and Sheridan townships is merely the most tuffaceous member of a number of outcrops which are all more or less pyroclastic in their composition and which are found along the road and in the river in this neighborhood. In speaking of this locality Hitchcock[1] notes the

[1] Agriculture and Geology of Maine, 1861, p. 391.

presence of "very coarse conglomerates and trappean rocks," and of sandstones, "friable slates," "fine gray grits," and "conglomerates" farther to the west. All the varieties mentioned are composed wholly or in part of volcanic débris, and range in size of grain from microcrystalline to conglomerates with pebbles an inch or more in diameter. The coarser and finer tuffs are interbedded with the more typical sandstones and conglomerates, and give the appearance of dikes or beds of hard-baked feldspathic clays. The coarse tuff in particular resembles an igneous rock, and microscopic examination is required to determine its true character. It is doubtless on this account that the State survey overlooked the ash deposits of the region.

PETROGRAPHY.

CASTLE HILL TUFFS.

The same division of the Castle Hill tuffs into normal type and silicified type will be made here as in the field description.

Normal type.—This has its best development on the southeast base of Castle Hill, where it forms all the rock exposures seen, with the exception of the andesites on lot 31 (see map, fig. 6, p. 120). The ash on the west side of the wagon road contains the most numerous glassy fragments, as viewed by the unaided eye. It is light lead-colored on fresh surfaces and full of lapilli, which appear as white areas specked with black dots, made by calcite filling minute cavities. The rock breaks into rough fragments, but more easily along lines of partly developed cleavage or shearing. Weathering first forms a sandy coat very uneven in thickness, and finally the rock changes to a crumbling breccia. Specimens picked up from any part of the field show evident tuffaceous characters. The microscope shows the rock to be more than half composed of lapilli, which are present in two forms. These forms are as follows:

1. Lapilli composed of particles of white dust, which are isotropic, very angular in outline, with cusps, crescents, and sherds. In places the angles are rounded off and replaced by black dust, and again the characteristic outline of a former sherd shows, which is no longer glassy, but filled up with iron dust. They occasionally contain vesicles and show gradations in size up to—

2. Lapilli one-half millimeter in diameter, of white glass, perfectly isotropic, and filled with vesicles which may be large or small, separate or in coalescent groups. These vesicles are usually round, but occasionally are drawn out into ellipses and are now filled with secondary calcite or rarely with chlorite in radial growths. Boundaries of the lapilli are made of concave recesses between projecting cusps formed by bursting of steam pores along the edge of the glass fragment. These larger lapilli show areas devitrified into feldspar laths with

quartz, and again are broken up into dusty iron patches within the general lapilli boundary. The few feldspar crystals present are too badly altered to calcite to be definitely determined, and little aggregates of calcite grains and crystal sections are sprinkled through the whole groundmass.

Pl. XIV, *B*, shows the typical tuff for this region.

Some variations from this typical lapilli-filled tuff will be here briefly mentioned.

In the road running north-south along the east of Castle Hill the rock has much more the appearance of an argillaceous sandstone, and its ashy character is only revealed by weathering. The microscope shows quartz grains and fragments of andesitic material in addition to the vesicular glass and lapilli.

A specimen collected near the main outcrop of the normal type, as described above, was found by microscopic examination to be composed of large glassy fragments mixed with a few feldspar rods. The bubbles in the vesicular igneous fragments are elongated and arranged rudely in rows. The whole structure suggests a lava stream which had been blown to fragments while in process of flow. The rock is now stained with iron and dotted with chlorite, while the interspaces and vesicles are filled with calcite.

The material forming the Richardson Hill knob, and also that near the silicified tuff on lot 31, contains few lapilli, but much vesicular lava, quartz, and feldspar, and in some of its varieties passes into the volcanic conglomerates which are without fragments of glass.

On lot 31 there is a coarse variety of ash, loose-textured where exposed to the weather, and composed of angular and subangular grains of quartz and various volcanic fragments. The larger fragments are so firmly embedded that they break across when the rock is broken. A few fossils, mostly corals, are embedded with the rock fragments. The microscope shows all the grains to be angular, some remarkably jagged, and to consist of quartz in individuals or groups; feldspar, untwinned or with Carlsbad or albite twinning, and occasionally microperthite intergrowths; light-colored trachytic and andesitic fragments; microcrystalline masses of quartz and feldspar marked by perlitic cracks and representing devitrified glass, and finally lapilli with vesicles and characteristic outlines.

These looser-textured fossil-bearing ash beds on the southern slope of Castle Hill could scarcely be distinguished in the hand specimen from the sandstones of the Livingston formation in Montana,[1] and the presence of abundant andesitic fragments is common to the material from both localities.

[1] W. H. Weed, Bull. U. S. Geol. Survey No. 105. Weed and Pirsson, Bull. U. S. Geol. Survey No. 139, pp. 49 et seq.

Analysis.—The following analysis of tuff of the normal type from Castle Hill was made by Dr. W. F. Hillebrand, of the United States Geological Survey:

Analysis of tuff of the normal type from Castle Hill.

Constituent.	Per cent.	Constituent.	Per cent.
SiO_2	31.42	V_2O_3	.06
Al_2O_3	11.57	NiO	Trace.
Fe_2O_3	2.37	MnO	.38
FeO	7.48	BaO	.64
MgO	5.32	SrO	None.
CaO	16.71	Li_2O	Trace.
Na_2O	2.26	P_2O_5	.46
K_2O	.74	CO_2	13.13
$H_2O-105°$	.76	Cl	?
$H_2O+105°$	4.17	Fe	?
TiO_2	2.30	FeS	.16
ZrO_2	None.		99.93
Cr_2O_3	Trace.		

Discussion of analysis.—In regard to the barium present in the tuff, Dr. Hillebrand says: "The barium exists as silicate, since the sulphur is all pyritic, and it does not appear as carbonate."

Silicified tuff of Castle Hill.—The specimens of this tuff from the ledge east of the mouth of Welts Brook are black, exceedingly dense, hornstonelike rocks, with a fracture approaching the conchoidal, and have the appearance of metamorphosed siliceous breccias. The black groundmass is mottled with light greenish-gray areas, which are proved to be glasss by microscopic examination. Numerous cubes of pyrite with striated faces form a prominent macroscopic feature. Areas a square inch or more in extent, composed largely of small grains of jasperlike material, appear on the surface. Quartz-filled cracks intersect the specimen, and weathering does not proceed rapidly on exposed surfaces.

Microscopically the rock is practically a mass of glassy fragments thoroughly cemented together with silica. The larger and many of the smaller lapilli are greenish yellow in the section and are sometimes 2 millimeters in diameter. They are divided into polygonal areas by dark lines, which appear to be incipient cracks filled with opaque material. The glassy fragments are broken and separated into distinct pieces, or split part way across, leaving wide cracks, now filled with siliceous cement. Areas are found composed of a mass of lapilli with cusps and concave spaces forming the outer border and having vesicular

structure within. These areas are in part devitrified and composed of quartz grains, but they always retain their vesicular structure. In other places devitrification has progressed until only dusty, opaque spheres remain in a quartz groundmass. Iron pyrite and grains of red jasper are quite generally distributed. With the exception of the structures described, the rock is siliceous. Sometimes the quartz is arranged as a tiny geode; sometimes there are areas of quartz bounded by a faint dark outline when viewed in plain light, and everywhere throughout the section groups of interlocking grains or individual grains, seen only with the highest magnifying powers, are present to the exclusion of other minerals and alteration products. The rock is considered a good example of a highly acid tuff now completely silicified.

TUFF IN NORTHEAST PART OF ASHLAND TOWNSHIP.

The tuff from this locality appears in the coarser variety as a dense blue rock, in which are found greenish-gray rounded and angular lapilli an eighth of an inch and less in diameter, whose aggregate amount comprises more than half the whole specimen. In weathering, the little spherical lapilli alter to a white porous substance, while the entire mass weathers dirty brown, giving the whole surface a peculiar spotted appearance, which has given rise to the idea that the structure is amygdaloidal, and it has been described as such.

Microscopic description.—Microscopic examination of sections cut from the finer-grained specimens collected at this place showed their unmistakable tuffaceous character, but they were too decomposed to be studied in detail. The coarser tuff, however, was seen to consist of rounded, pumiceous areas set in a groundmass composed almost entirely of minute lapilli, with their characteristic jagged and concave outlines. The spherical masses also are composed of minute glassy fragments. In addition to these glassy components, the rock contains a few feldspar crystals, some fragments of mica, and areas of devitrified glass.

The rock is but slightly stratified, if at all. The fragments are all small and very angular, and minute glassy particles are abundant. These facts indicate an air-laid breccia.

TUFF ON THE ASHLAND-SHERIDAN ROAD.

The bed of volcanic tuff near the Ashland-Sheridan line appears as a dark-gray, mottled rock of light and dark areas, the nature of which is not evident in the hand specimen. Under the hammer it breaks into irregular fragments, and is traversed by a set of cleavage planes. Where it is much weathered the rock is not distinguishable on the surface from the volcanic sandstone with which it is associated.

Microscopic description.—Under the microscope the slide presents some interesting features. The general mass is formed of areas composed of groups of feathery feldspars which branch and assume broomlike or bushlike forms. Often the brooms are arranged radially and have branches similarly arranged, and in such cases the ordinary spherulitic cross is seen between nicols. It seems evident that these areas are of devitrified glass, and it is possible that some glass still remains. Other areas are made up of feldspar laths with trachytic structure and having their interstices filled with quartz grains.

The most unusual feature about the rock is the presence within the trachytic parts of aggregates of grossular garnets in well-developed crystals and irregular grains. With the garnets are associated quartz grains or calcite, rarely both, and in plain light the areas thus composed usually present a distinct polyhedral outline, as if some original mineral had been replaced. The origin of the garnets is not understood. It seems improbable that they should have been infiltrated into the rock in their present condition and occupy only particular places, and that of all the rocks of the region this tuff bed alone should contain them. They may, however, be due to metamorphism of some included fragment, as suggested by Osann[1] in the case of the andesites from Hoyazò, Cabo de Gata; but in the Maine tuff the original fragment is represented by a distinct polyhedral outline and hence could not have been an irregular schist pebble, but rather some crystallized mineral.

A piece of augite was found in the rock, and also a few badly altered feldspars. The alteration products are distributed in accordance with the materials composing the tuff—chlorite in the glassy areas and calcite among the trachytic fragments. The latter mineral occurs also in patches throughout the rock and as the filling of the cleavage cracks.

VOLCANIC SANDSTONES AND CONGLOMERATES.

As more fully explained at the beginning of this chapter, volcanic sandstones and conglomerates include all those clastic rocks composed principally of fragments of igneous materials. They are usually not much waterworn or rounded, and indicate rapid deposition of material from a source not far distant. The separation of this class from the tuffs described in the last section is purely arbitrary and not indicated by field relations; and furthermore, even when examined in thin section the two classes of rock are found to grade into each other. In amount of igneous material the volcanic sandstones and conglomerates range from those containing practically nothing else to those in which half or more of the rock is of quartz and sedimentary fragments.

[1] Zeitschr. Deutsch. geol. Gesell., Berlin, Vol. XL, 1888, p. 705.

FIELD DESCRIPTION.

These rocks have been found on Welts Brook, west of Haystack; on the Ashland-Sheridan road south of the volcanic tuff described in the preceding section; in Perham Township, outcropping in the road running east-west along the south side of the Little Madawaska ponds; in New Sweden Township, at the headwaters of and all along Bearsley Brook; and on the east shore of Madawaska Lake.

VOLCANIC CONGLOMERATE ON WELTS BROOK.

This outcrop is in the line of the road running east-west on the north side of Haystack Mountain, and forms several low ledges a short distance east of the brook. In the field the rock appears as an indurated sandstone, varying in texture from very fine materials to conglomerates with fragments of slate 6 inches long. Fossils of several species were found here more abundantly in the coarser parts. A rude bedding is indicated by a succession of coarse and fine materials, but the variation is never abrupt and is rarely distinct enough to determine the position of the beds. The rock here is exposed for 100 feet or more along the bedding, and farther to the northeast similar material is found quite abundantly on lot 89, Castle Hill Township.

VOLCANIC CONGLOMERATES OF ASHLAND TOWNSHIP.

These occur in the road running northeast from Ashland and about 2 miles from that village. In the field this particular outcrop is not distinguishable from the other sandstones and conglomerates of Ashland and Sheridan townships. In fact, the field evidence shows that all the conglomerates of this region, ranging in texture from fine grits to exceedingly coarse pudding stones, are parts of one series of beds, laid down under different conditions. Igneous material is in them all, and the present example, like the volcanic tuff next to it, is separated from the Sheridan sandstones on the arbitrary line of relative amount of volcanic débris contained. The beds are fossiliferous, and strike N. 25° E., with dip $< 40°$ NW.

VOLCANIC CONGLOMERATES OF NEW SWEDEN TOWNSHIP.

This rock is quite widely exposed about the headwaters of Bearsley Branch of Madawaska River, and also on the north bank of the stream about the middle of the township, and, in fact, forms practically all the northwest half of the township. The best exposure is a hill on the west line of New Sweden, on the south side of the little brooks which form the headwaters of Bearsley Branch. A continuous section is exposed here for about half a mile, and shows coarse conglomerates, sandstones, and arenaceous shales in beds 1 to 35 feet thick, forming a series which in position and material is practically the same as the one

found on the Aroostook River in Sheridan Township. The strike of the beds is N. 60° E., with dips which indicate an anticline. With the exception of one dense indurated specimen, all these rocks show, in the field, their rapid deposition and their origin from igneous fragments, and here, as in Perham and Sheridan, the most characteristic field mark is the presence of little fragments of slates which might be mistaken for plant remains.

VOLCANIC CONGLOMERATES OF PERHAM TOWNSHIP.

Outcrops occur in the valley of Salmon Brook, where it is crossed by the wagon road running east-west through Perham Township, about one mile south of the north township line. The section here presented begins at the schoolhouse on the east bank of the stream, with thin slates whose cleavage planes run N. 40° E., which are succeeded by fine, gray sandstones with slate and other fragments, striking N. 20° E., dip E. $<$ 75°. The sandstone on the west bank of the stream is very light gray, fine to medium grained, and is not distinguishable in the field from the volcanic sandstones in New Sweden and Sheridan, and, like them, contains few fossils.

There is every indication that the three sections of volcanic conglomerate described are sections across the strike of a narrow belt of sandstones and conglomerates extending from near Ashland Village to the north line of Perham Township.

VOLCANIC CONGLOMERATES OF MADAWASKA LAKE.

These are found typically exposed on the east shore of Madawaska Lake near the wagon road. Along the shore and in the lake bed the rock is seen broken into massive blocks by intersecting cleavages. On the west the sandstone is bounded by reddish slates. The general rock structure and field relations closely resemble the Perham conglomerates, and are classed as part of the same general belt.

PETROGRAPHY.

VOLCANIC CONGLOMERATE ON WELTS BROOK.

The finer varieties of volcanic conglomerates found at this point appear in the hand specimen as medium-grained sandstones, gray in color and much hardened. Most of the grains are not determinable by the unaided eye, but a few quartzes and feldspars attain the size of buckshot, and in the coarser varieties fragments of quartzose rock and of black, green, and reddish, extremely dense slates, one-half inch to 1 inch in their longest diameters, with subvitreous luster, are abundantly found. They are so firmly embedded that they break with the rock. Weathering proceeds very slowly and very unevenly, so that parts of the rock are decayed to great depth, while other parts equally exposed

re too well silicified to admit water, and hence remain quite fresh at he surface.

The microscope shows the rock to contain quartz and feldspar grains, vith fragments of various igneous rocks. The quartz occurs both as artially rounded grains and as secondary filling of cracks. Feldpars, with orthoclase more common than plagioclase, are found in vell-formed crystals, untwinned or with Carlsbad or albite twins, and nicroperthite intergrowths. The fragments of volcanic rock include ndesite and trachyte, with a groundmass of ragged feldspars, often rranged in flow structure; fragments, perhaps of formerly glassy mateial now devitrified, showing feldspar needles in a dark cryptocrystalline roundmass, and fragments of vesicular lava with some glass formed y steam blowing back in the vesicles. Besides these evident volcanic naterials, which constitute the bulk of the rock, there are also green, lassy-looking fragments—microcrystalline—which may be metamorhosed slates. Most of the components are with angular outline, nd have associated with them chlorite and calcite with beautiful twin amellæ.

VOLCANIC CONGLOMERATES OF ASHLAND TOWNSHIP.

The volcanic sandstones and conglomerate from this locality range rom dense sandstones to coarse varieties, but typically have very ngular grains 2 to 3 millimeters in diameter. The rock contains so nuch calcite as to resemble a finely brecciated limestone in places, nd to cause it to effervesce freely with acid. It is blue gray in color, veathers to a white gray, and bears close resemblance to the rock xposed in Ashland Village, interbedded with the fossiliferous imestone.

Under the microscope the following components are seen: Quartz n large, broken, angular to rounded, interlocking grains, and small rains filled with inclusions, and feldspar represented by a few crystals ow altered to calcite and volcanic fragments. The fragments of gneous rock comprise most of the material and are largely of andesite, nd many large and small fragments of vesicular feldspathic lava with low structure well developed. There are also areas with a pepper and salt appearance, which is taken to represent former glassy material or siliceous silt. Some mica is present, and calcite is abundant as a secondary product, and probably also primary as cement.

VOLCANIC CONGLOMERATES OF NEW SWEDEN TOWNSHIP.

This rock presents considerable variation in the field, and specimens from twelve different localities were collected for comparison. The coarsest variety is a dark, unassorted mass of angular and subangular fragments of quartz, andesitic and rhyolitic materials, granite, black and greenish glassy siliceous slates, and soft black slates, all set in a

cement of similar materials. The fragments are at times 3 inches in the longest diameter, and the larger siliceous fragments show agate and geode structures.

The medium-grained varieties pass into sandstones and are light gray in color and marked by many small, black slate fragments of somewhat larger size than the general mass, but otherwise the rock is of very uniform texture. There occurs a variation from this medium-grained type, in which the angular grains are quite widely separated by an unusual amount of finer-grained cement and in which occasional disks of slates an inch or more in diameter are found. On weathered surfaces these three varieties show the siliceous fragments projecting above the more readily dissolved cement, and their extreme angularity is thereby well displayed. Fossils are sparingly found in all these rocks.

A fine-grained variety is dark bluish gray on fresh fractures, and weathers white gray along zonal lines, which are quite distinctly marked. No grains in this are large enough to be distinguished with the unaided eye, except the ever-present black slate fragments. One variety is so dense, indurated, and fine textured that it resembles igneous rocks of felsitic character and its nature is only revealed by the microscope.

Microscopic description.—Several slides were prepared from the different varieties which showed close similarity in all points except size of grain. The medium-grained variety was taken as typical and was found to contain quartz and feldspar, with some accessory materials, in addition to the fragments of volcanic rock, which are the most abundant of all the components. The quartz is in broken, cracked, angular and subangular grains—none round—about one millimeter in longest diameter. Feldspar includes both orthoclase and oligoclase, the latter with bright lamellæ. The lava fragments are rhyolite, trachyte, and andesite, with the first two more abundant and with flow structure. Sedimentary material is represented by a few fragments of arkose and slate. Zircon grains are sparingly present. The cement is of fine material, identical in composition with the larger fragments, but altered to a yellow micaceous substance. Another variety is so largely composed of andesitic fragments as to deserve the name of andesitic tuff. The dense, indurated variety mentioned above is found to be made up of quartz grains and fragments of siliceous lavas. In all the varieties of volcanic conglomerates from New Sweden, so far as examined, microscopic fragments of brachiopods and other fossils were found.

VOLCANIC CONGLOMERATES OF PERHAM TOWNSHIP.

The volcanic conglomerates of Perham Township present a dark bluish-gray variety, in which the components are not megascopically discernible, and a light-gray variety of medium grain, occasionally con-

aining a large disk of some shaly material. They are fossiliferous, and t times the fossils occur as the center of balls an inch or more in liameter which are composed of material similar to the general rock nass, but which maintain their individuality and in weathered specinens drop out of the rock as spheres, or are easily removed with the ammer.

Microscopically this rock shows no peculiarities which distinguish t from the types described above, but consists of quartz grains, feldpar crystals, fragments of igneous rock of rhyolitic, trachytic, and ndesitic facies, with practically no fragments of sedimentary rocks. The cement is of the same material as the grains, and is usually dusty nd of dark color.

VOLCANIC CONGLOMERATES OF MADAWASKA LAKE.

The volcanic conglomerates of Madawaska Lake appear in the hand pecimen as a dark-gray rock of rather fine grain, which on weatherng forms an ashy-gray outer zone. Round or oval balls as large as eggs orm a prominent field character, and are found abundantly embedded n the sandstones. They maintain their individuality through all states of weathering, and can be seen firmly set in the fresh rock, or partly oosened and resting in sockets, or as detached spheres along the lake hore (see Pl. IX, *B*). These balls are of different material from he sandstone, and when broken open are found to contain no fossils nd to show no concretionary structure.

The microscope shows the sandstone to be composed of angular and ounded grains of quartz, abundant feldspars, often striated, and many ragments of rhyolitic and andesitic lavas. The slide prepared from n embedded sphere showed but few quartz and feldspar fragments, out instead was seen to be practically composed of fragments of a basic ava and augite crystals. The cement is of fine material of similar ature with considerable calcite added. It seems evident from this lissimilarity of composition that the embedded ball is a worn fragment of some fine-grained volcanic conglomerate already in existence at the ime the Madawaska volcanic conglomerate was forming.

SANDSTONES AND CONGLOMERATES.

By referring to the table of classification given at the beginning of his chapter, it will be seen that sandstones and conglomerates include ll the rocks of sandstone habit whose principal component is quartz. According to the amount and character of the other components, five livisions are made, as seen in the table referred to. These divisions re arbitrarily made for the most part, and it is possible to supply the ransition forms. It is also true that no sharp line can be drawn between the volcanic conglomerates and the sandstones composed

partly of igneous material, and at the other end of the series there is likewise no evident line of separation between the calcite-bearing rocks and the gritty, partly calcareous layers in the limestone.

In size of grain these rocks range from very coarse conglomerate to microscopically fine-grained arkoses. All these variations will be grouped together and described according to their geographic occurrence as Sheridan sandstone, Chapman sandstone, Mars Hill conglomerate, Mapleton sandstone, and sandstones from other localities.

SHERIDAN SANDSTONE.

This series is mentioned in Hitchcock's report[1] by Packard, who also[2] describes a smaller section on Fish River Lakes. Bailey[3] has also described the beds quite fully and has given a list of the fossils contained in them. As stated above, these sandstones form one continuous series with the volcanic conglomerates of Ashland and Sheridan, and are interbedded with them. Two parallel sections through these rocks were studied, the first on the State road, which follows the Aroostook River, the second in the bed of the river itself.

In the river section the rocks exposed for about 2 miles below the Ashland sawmill are argillaceous and arenaceous slates, red, gray, and green in color, with an occasional embedded fragment of black slate. Interbedded with the slates are thin layers (one-eighth of an inch to 10 inches) of greenish-gray calcareous material that weathers more readily than the slates and resolves itself into a mass of broken crinoid stems. These slates strike N. 20°–40° E., and dip SE. $<60°$, while the slaty cleavage plane dips W. $<50°$. Succeeding these slates the river runs through sandstones and conglomerates for nearly 4 miles, while the outcrops along the wagon road repeat and supplement the section thus exposed.

Fine-grained variety.—Of the river outcrops the one about one mile west of the east Sheridan line, and known locally as "Alley's grindstone," will be taken as typical for the finer-grained varieties. This outcrop is composed of three series of beds, as follows:

1. A very fine, even-grained sandstone, light gray or almost white in places, which attains a thickness of 20 feet and is broken into large blocks by cross fractures. Under the microscope a thin section of the rock shows quartz in angular and subangular grains, often in interlocking groups, and feldspars which are kaolinized orthoclase and fresh-looking plagioclase. The feldspar and quartz constitute about 90 per cent of the rock, but there are in addition many small fragments of slate, a few of igneous rocks of micropegmatitic character, and rarely biotite and zircon grains (see Pl. VIII).

[1] Agriculture and Geology of Maine, 1861, p. 425.
[2] Op. cit., p. 423.
[3] Ann. Rept. Geol. Nat. Hist. Survey Canada, 1887–88, Pt. M, p. 45.

(A)

(B)

(A) FINE-GRAINED SHERIDAN SANDSTONE.
(B) SHERIDAN SANDSTONE.

2. Beds a foot or more in thickness, somewhat coarser, but otherwise practically as above in general texture. They contain much larger and more numerous fragments of slate, and, as has been noticed by others,[1] several species of fossils which seem to decay readily and give the rock an amygdaloidal aspect. These two varieties are ordinarily separated by—

3. Beds of very fine brown sandstone, one-half inch or more in thickness, which show mud cracks and appear as fine consolidated beach muds. The rocks of this section, particularly of the gray fossiliferous beds, are duplicated near the store and church at Frenchville. The position of these fine beds on the river is, strike N. 100° E., dip S. $< 10°$. All the beds in this neighborhood have this strike, but the dip rises to 50°–60°.

Coarse conglomerate variety.—This is abundantly exposed along the State road, where it forms ridgelike hills, which are crossed by the road. Massive ledges of it outcrop on the river, and loose bowlders, sometimes 20 feet or more in diameter, lie in the stream and along the bank. All these conglomerates are practically identical in composition, but differ in amount of induration from loose sandstone to very compact specimens cemented with quartzitic material. Usually the alteration between coarse and fine strata occurs every few feet, but continuous layers of conglomerate with a thickness of 10 feet and more were observed.

The pebbles exposed by weathering are at times 6 to 8 inches in their longest diameter and are subangular to rounded in form. The pebbles found in these conglomerates are: quartz; granite; red, white, and greenish jaspers, agate, and other siliceous fragments; pieces of black slates; sandstones; quartzite; felsitic igneous rock; spherulitic andesite; porphyritic and amygdaloidal lavas. Of these components the siliceous subvitreous-looking fragments are most abundant and durable (see Pl. IX, *A*).

A thin section examined under the microscope showed the cement to be largely of rounded or subangular quartz and feldspar grains, often with striking intergrowth. The great variety of fragments of sedimentary and igneous rocks and of minerals present is unusual.

CHAPMAN SANDSTONE.

This sandstone covers a considerable area in Chapman Township and was examined at four outcrops: On the main road west of Quoggy Joe, on the south branch of the Presque Isle near Tweedy's, in the road near the southwest corner of the township, and at Edmunds Hill.

The most interesting occurrence is that on the Presque Isle River, and this will be described as representing them all. Here the rocks

[1] Bailey, Ann. Rept. Geol. Nat. Hist. Survey Canada, 1887–88, Pt. M, p. 45.

are exposed along the stream for about a quarter of a mile and show sandstones interbedded with slates, both having a uniform positio with strike N. 80° E., dip W. < 50°. The sandstone is dark gray fine grained, and uniform in texture, never approaching a conglomerate. Where fresh it presents a crystalline appearance much lik quartzite. This is more particularly applicable to the Edmunds Hil sandstone.

Interbedded with these gray sandstones are thin beds of soft, yellowish, micaceous shales, which are often nodular and flaky, with irregular bedding. Embedded in this shaly layer on the side next the sandstone is a solid mat of fossils—mostly brachiopods and lamellibranchs—together with many plant impressions and occasionally carbonized remnants of vegetable forms. With the fossils, or embedded alone in the edge of the sandstone, are pebbles of slate and of limestone at times 2 inches or more in length. These facts indicate that the Chapman sandstone was formed on a beach which was probably washed by tides or currents and overhung by cliffs composed of calcareous materials.

Under the microscope the rock is seen to contain quartz, feldspar, and fragments of sedimentary material. The quartz constitutes three-fourths of the slide and occurs as rounded and angular grains, rarely interlocking and embayed, and often with dust inclusions. Feldspar crystals are few and usually are not well preserved. The rock fragments present are nearly all long, oval pieces of slate, and no undoubted igneous material was found. There are a few grains of garnet and zircon, and much stringy micaceous and chloritoid material, which, mixed with quartz and calcite, forms the cement.

MARS HILL CONGLOMERATE.

Mars Hill is the most prominent landmark on the international boundary. All about the mountain and up to its very base the ordinary slated limestones of the region form a rolling plain about 500 feet above sea level. Above this the mountain rises to a total height of 1,695 feet above tide, as measured by the aneroid, and covers an area about 2½ miles long and half a mile wide. It is densely forested except at two localities on the southwest corner and a partly cleared area at the north end. This makes a final determination of structure and composition impossible at present.

The mountain seems to have been first visited for geologic purposes in 1838, when Mr. Hodge, of Dr. Jackson's party, found here and there "outcropping ledges which proved on examination to be grauwacke, exactly like that on Sugar Loaf Mountain, and like that rock belonging to the regular Anthracite Coal Measures."[1] Hitchcock[2] refers to

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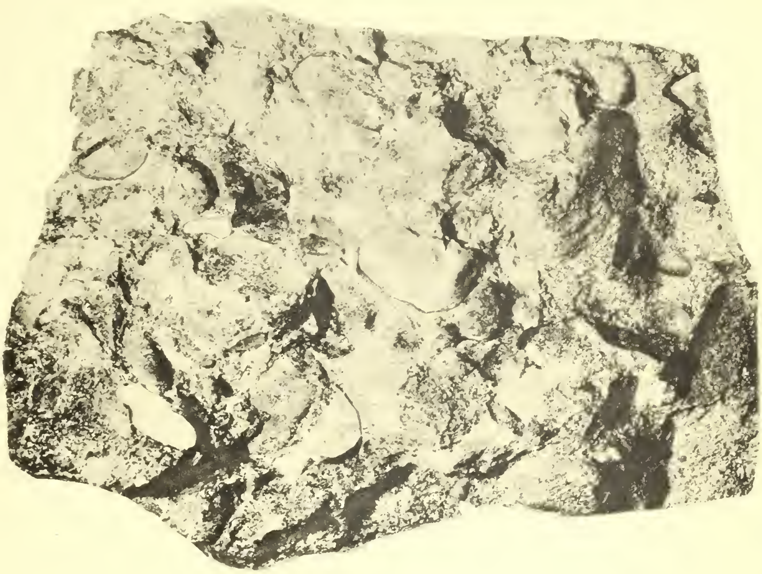
[1] Jackson, Second Ann. Rept. Geol. Public Lands, 1838, p. 46.
[2] Agriculture and Geology of Maine, 1861, p. 386.



(A)

(B)

(A) CONGLOMERATE OF THE SHERIDAN SANDSTONE SERIES.
(B) SANDSTONE FROM MADAWASKA LAKE.

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these rocks as Devonian sandstone, and states that they are of the same age as the red sandstones of Mapleton.

Rock structure.—With the exception of the igneous rock described in another chapter, Mars Hill is composed of a conglomerate which in places becomes quite fine grained. The structure of the mountain and the relation between the different rock formations are shown by the section, fig. 7.

The section is made straight east from the Boynton schoolhouse to the top of the mountain.

Near the schoolhouse occur the sandy, calcareous slates of this region; nearer the hill is a layer of very fine sandstone, about 50 feet wide, which is composed of quartz grains with some feldspars set in a calcite cement. Extending from this sandstone to the base of the hill, a distance of about half a mile, is a whitish to blue brecciated limestone, which is closely folded and faulted and cut by cleavage planes that are now filled by secondary calcite. The limestone is not uniformly calcareous, but contains sandy streaks, especially near the hill.

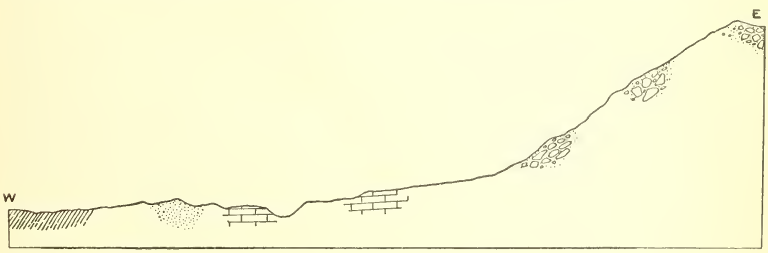


Fig. 7.—Section at Mars Hill.

The lower slope of the hill is of medium-grained breccia composed of fragments of sandy slates and sandstones, which soon passes into a very coarse, rough breccia composed of large fragments of sandy and argillaceous slates, together with fragments of arkose and other varieties of sandstone and rarely a fragment of an igneous pebble. The fragments are subangular. The whole mass is slated and sheared and has all bedding lines destroyed.

From halfway up the mountain to the top the slate fragments, which are so abundant below, disappear as the predominant element in the rock, and are replaced by pebbles of sandstone, arkose, quartzite, hardened slates, and white quartz. The pebbles are rounded and vary from those that are fine-grained to those 4 inches and more in diameter. The cementing material is very firm, as is shown by the fact that the cleavages break through the pebbles.

The sandstones and conglomerates exposed on other parts of Mars Hill are much like those in this section, and show variation in fineness and amount of induration.

Microsections cut from the rock at the north and south ends of the mountain revealed the same composition, although varying in relative size and abundance of the compound fragments. The materials found are rounded, lengthened fragments of sandy schists or slates, which have been bent and stretched, and rounded fragments of sandstone composed largely of quartz and feldspar grains, which in places are broken into parts that have moved since fracture. The general cement is of quartz grains, with some feldspar and numerous sheared fragments of slate.

The Mars Hill conglomerate is quite distinct from all other sandstones and conglomerates so far found in northeast Maine. The absence of igneous fragments is noticeable, and the great abundance of slate fragments makes it almost a slate conglomerate. The sheared and broken condition of the whole mass and of its individual pebbles, and its intimate association with the crumpled and brecciated slates and limestones at its base, indicate an age at least as great as the Aroostook slated limestone, and it is considered, on lithologic grounds alone, to belong to that series.

MAPLETON SANDSTONE.

Nearly all the eastern half of Mapleton Township is overlain by red sandstones and conglomerates, which form rounded hills, with many good exposures. Outcrops occur on the State road about 3 miles from Presque Isle and on the Mapleton road about 1½ miles from the village.

Winslows Hill section.—This section affords the best opportunity for study. An east-west road that branches from the State road about 1½ miles from Presque Isle Village runs over the top of the hill and crosses the strike of the different beds. The outcrops on the hill form a reasonably complete series, and will be described as representing the whole Mapleton sandstone area. Beginning at the east base of the hill and extending about halfway to Winslow's house is a series of reddish-brown sandstones and coarse conglomerates in beds 10 to 30 feet thick. The heavier beds of conglomerates are near the bottom and become inconspicuous toward the top of the hill. The compact beds of fine red sandstone appear to be first-class building material, although the dip into the hill will make quarrying expensive.

Above these coarse and fine red rocks are other fine-grained sandstones, which are gray in color and have much the appearance of the Chapman sandstones. They form the top of the hill, and occur in thick beds, with an occasional stratum of coarse material a few inches in thickness.

The thickness of the whole series as exhibited by this section is 215 feet, of which 180 feet is of the red sandstones and conglomerates.

The strata dip NW. $< 15° \pm$ and have an average strike N. 45° E. The section is shown in fig. 8.

Petrography.—The conglomerate varies from fine consolidated gravel, partly water sorted and marked by cross bedding, to a confused mass of pebbles 2 to 3 inches in diameter. The pebbles contained are quartz, reddish and greenish jasperlike fragments, blue limestone, white limestone, calcareous slates, quartz-porphyries, and occasionally fragments of other igneous rocks. Thin sections examined under the microscope show that the fine sandstones are practically identical with the conglomerates in composition, and that the cement of all the varieties is largely calcareous, with a mixture of iron.

In the red sandstones near the hilltop are abundant remains of a branching Psilophyton and other Devonian plants, but diligent search has failed to reveal other fossils (see Pl. XII, *A*).

Field relations.—At no place was an actual contact between the Mapleton sandstones and the common slated limestones of this region observed, but outcrops of the two formations were found near each other in several places, and wherever seen the limestones are much folded and slated and dip at high angles, while the sandstones dip

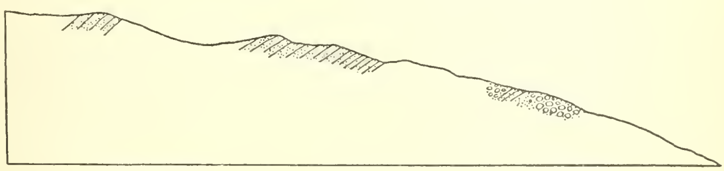


FIG. 8.—Section through Winslows Hill.

slightly and show little disturbance since deposition. On such evidence it is believed that the Mapleton sandstones lie unconformably upon the slated Aroostook limestones.

These sandstones were examined by Hitchcock,[1] who called them Devonian. The field measurements which he made could not be verified. Bailey[2] considers them to be of Lower Carboniferous age, and in describing this region appears to extend the sandstone area, and mentions vesicular gray sandstone 4 miles from Presque Isle, presumably on the Haystack road. In this vicinity, however, no rocks were seen except many outcrops of decayed porphyritic andesite.

SANDSTONES OF OTHER LOCALITIES.

Outcrops of a fine-grained sandstone with a decided quartzite appearance and fracture are exposed on Johnsons Brook, New Sweden; on the North Branch of the Caribou in Woodland; on the Aroostook

[1] Agriculture and Geology of Maine, 1861, p. 425.
[2] Ann. Rept. Geol. Nat. Hist. Survey Canada, 1887-88, Pt. M, p. 47.

River in Wade Township; at Masardis, and in railroad cuts south of Masardis. The exposures are usually but a few feet wide and can seldom be traced for more than 100 feet. They form thin beds in the slates and limestones and remain as small ridges after the softer sediments have been worn away.

In thin section under the microscope they appear as an aggregate of quartz grains closely united, and with them considerable calcite is found, both in grains and as the cementing material. A few shreds of white mica, iron grains, and feldspars are usually also present.

These lime-bearing sandstones are geologically unimportant, and are mentioned to show their lithologic relationship. As indicated by the table given at the beginning of this chapter (p. 119), they are considered as a transition between the true sandstones and those with about equal amounts of quartz and calcite.

CALCIFEROUS QUARTZITIC SANDSTONE.

Under this head are included rocks of a peculiar type which have been called in the field felsite, quartzite, slate, and limestone. They occur as beds 15 feet or more in thickness, and as thin gritty layers in the limestone, and have a composition, as revealed by the microscope, of about half calcite and half other minerals, largely quartz.

These rocks are sparingly distributed in the eastern part of the section under discussion, and have not been found at all west of the Haystack Ridge. The outcrops easiest of access are at Washburn Ferry, on the north bank of the Aroostook River, and in the wagon road about 1 mile east of the Castle Hill Hotel. An outcrop in the northwestern part of New Sweden was found interbedded with fossiliferous slates by which its age has been determined.

Wherever the sandstone has been found it presents a light-gray, glistening surface, and looks in the hand specimens like a quartzite. It has an uneven fracture that is sometimes conchoidal, and it weathers by forming a distinctly bounded yellow-brown zone, immediately inside of which the rock presents a uniform fresh appearance. This method of weathering and the generally massive character of the beds are strikingly like many fine-grained feldspathic igneous rocks, and have given rise to confusion in field terms. Examination of microsections shows an exceedingly dense rock composed of calcite and other carbonates, quartz, feldspar, muscovite, and iron. The amount of quartz varies in different slides from about 50 per cent down to 15 per cent, but without greatly affecting the general quartzitic appearance of the rock. The muscovite is entirely absent in some slides and pyrite is occasionally present.

Analysis.—Owing to the uncertain character of this rock, Dr. W. F. Hillebrand made the following analysis of the specimen from New

Sweden Township, as this is the most highly calcareous and micaceous of all the specimens of this type collected:

Analysis of calciferous sandstone.

Constituent.	Per cent.	Constituent.	Per cent.
SiO_2	54.23	V_2O_3	?
Al_2O_3	7.38	NiO	None.
Fe_2O_3	.54	MnO	Not est.
FeO	1.37	BaO	None.
MgO	3.29	SrO	None.
CaO	14.56	Li_2O	Trace.
Na_2O	1.65	P_2O_5	.07
K_2O	1.74	CO_2	13.48
$H_2O-105°$	.25	Cl	?
$H_2O+105°$	1.22	Fl	?
TiO_2	.28	FeS_2	?
ZrO_2	?		100.06
Cr_2O_3	?		

The mineral components were calculated from this analysis and gave the following approximate composition:

Mineral.	Per cent.	Mineral.	Per cent.
Calcite	52.0	Siderite	2.1
Quartz	18.0	Kaolin	2.8
Alkali feldspar	13.7	Hematite	.5
Magnesite	6.9		100.0
Muscovite	4.0		

LIMESTONES.

Limestones are by far the most abundant and most widely distributed rocks of northeast Maine. They never occur as undisturbed beds, but are everywhere folded and slated and in places are brecciated to an extreme degree. Thick beds are rare, and generally the limestones are thin and uneven in bedding and interstratified with sandier materials, indicating the deposition of calcareous muds under the changeable conditions found near shore. Different specimens show considerable variation in the amount of material other than calcite present, and a series could be selected showing all gradations from the calciferous sandstone described above to the white fossiliferous limestone.

As shown by the table on page 119, limestone will include those calcareous rocks with considerable quartz, those with very little quartz, and those of calcite alone, and they will be described as arenaceous limestone, slated limestone, and white fossiliferous limestone.

ARENACEOUS LIMESTONES.

Rocks of this class occur as thin beds among the more calcareous members of the Aroostook limestone series, or as wide beds forming hills of considerable size. A good example is found in the railroad cut half a mile south of Presque Isle Station, and also in the road near the Academy Building, where the rock has the appearance of a quartzite sandstone interbedded with limy slates. It is cleaved and sheared, and has the recemented cracks common to the slated limestones. To the naked eye the rock is uniform in texture and composition, but under the microscope a thin section shows stratification caused by variation in the amount of quartz present in the different laminæ.

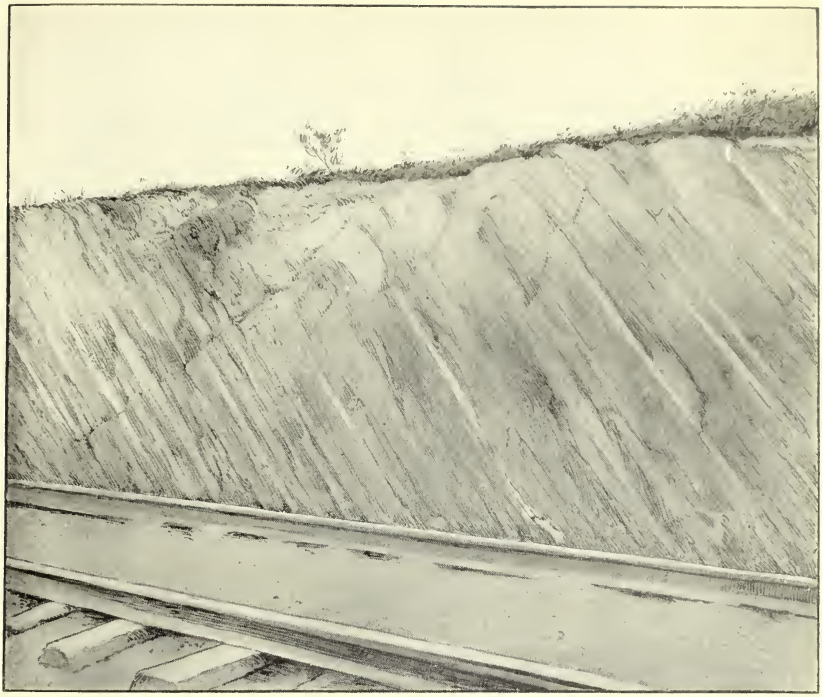
The largest exposures of this rock are on a hill about half a mile west of Spragueville and on the North Branch of the Presque Isle River, where it crosses the corner of Chapman Township. The rock is identical in both places, and only the Chapman section will be described. Rising from the river at Littlefields is a low, rounded hill or ridge, which is partly bare of vegetation and shows a number of good exposures. At the eastern base is a light-gray limestone, in places quite pure and uniform, but for the most part composed of angular fragments of limestone closely cemented together and containing numerous brachiopods and other fossils. This is apparently the same limestone as that observed on Dudley's farm, 3 miles to the northwest. In one place, near the northeast base of the hill, a contact between the white limestone and the arenaceous limestone was observed, and from the condition of the rocks it seems evident that crushing has taken place along the contact plane. A confused mass of pebbles of the two rock types now represents the contact.

Joining the fossiliferous limestone on the west is the arenaceous limestone, which is here shaly, weathers yellow brown in distinct zonal banding, contains many large, rounded nodules and lenticles of the same material, and is marked by Orthoceras fragments.

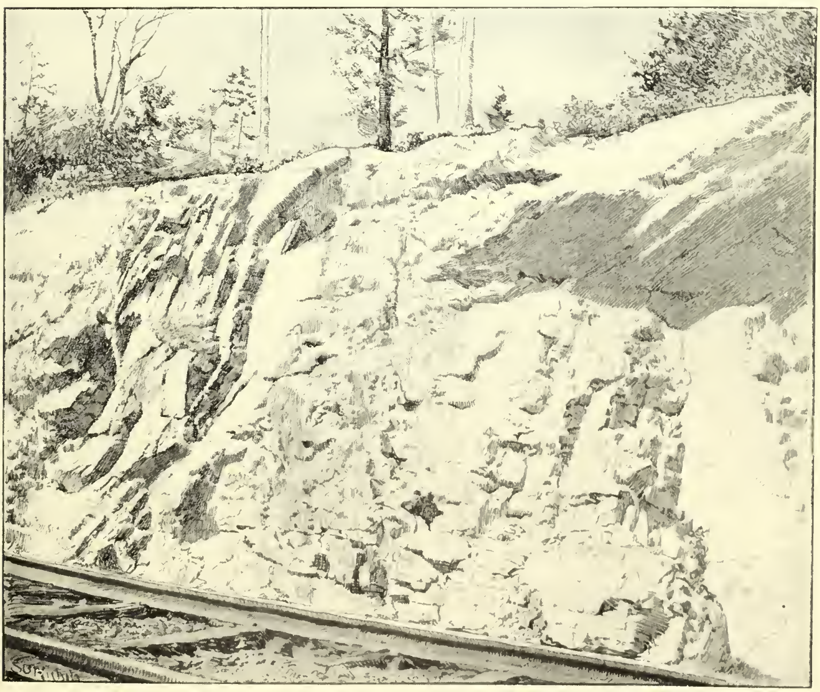
Farther up the hill the rock has a dark-gray color, is broken into thin slabs, and glistens with micaceous specks. The fossils here are graptolites. The rock nearest the hilltop is more sandy and contains crinoids, corals, and other organic remains.

Judging from the position of the fossils, the beds of this series strike N. 35° E. and dip W. $<$ 60°. Intersecting cleavage planes have broken the strata into blocks.

Under the microscope slides prepared from rocks of this class showed that calcite in rounded or irregular grains and in strings and



A. RAILROAD CUT AT HOULTON, SHOWING SLATED AROOSTOOK LIMESTONE.



B. RAILROAD CUT AT TIMONY ROAD, SHOWING FOLDED AND FAULTED AROOSTOOK LIMESTONE.

flakes constitutes about five-sixths of the material present, and that quartz grains, with a little muscovite and other accessories, compose the remainder.

Arenaceous sandstones of the same general character occur on the Aroostook River near the granite and along the railroad 2 miles east of Ashland Junction.

AROOSTOOK LIMESTONES.

This term is proposed for the thin-bedded, slated limestones which form the most widely distributed sedimentary rock type of this whole section of the North American continent. Its extent in northeast Maine is shown on the geologic map, and its yet more extensive distribution in New Brunswick and Quebec is shown by an examination of the Canadian reports. The Aroostook River has cut its wide valley through this formation from Wade Township to its mouth, and has revealed the rock structure at many points along its course. The St. John River also flows over rocks of this series, and at the Grand Falls presents a good section for study of its lithologic character. In general, the limestone area is a low plateau about 500 feet above sea level, with a rolling surface made by rounded ridges between slowly running streams. The valleys are in general broad, and the whole region indicates an advanced stage of topographic development.

Previous study.—The wide distribution of limestones has given this region rich agricultural land, which attracted settlers at an early date and gave the geologists the advantage of roads and cleared fields. The general monotonous character of the outcrops, however, gave little opportunity for special study. The members of the Jackson survey gave little information in regard to the series. Hitchcock briefly decribes the section from Houlton to Presque Isle,[1] and calls the rocks calcareous slates and limestones of Upper Silurian age.[2] The most complete study of the slated limestones has been made by Professor Bailey,[3] who reviewed the work of previous writers and described the New Brunswick area in detail. He regards the following as the probable succession of strata, in descending order:

Gray or greenish-gray (bluish weathering) argillites, with occasional alternating beds of greenish-gray sandstone.

Gray, green, and bright-red slates, holding heavy beds of manganiferous hematite.

Gray, highly calcareous slates, conspicuously banded on weathered surfaces, including at various points heavy beds of limestone, which are more or less fossiliferous.

Gray, calcareous, and buff-weathering sandstones and slates, holding remains of crinoids, corals, brachiopods, and graptolites.

Gray, calcareous conglomerates and sandstones, holding pebbles of Cambro-Silurian rocks.

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[1] Agriculture and Geology of Maine, 1861, p. 385.

[2] Geology of Northern New England, p. 3.

[3] Ann. Rept. Geol. Nat. Hist. Survey Canada, 1885, Pt. G, pp. 11-23.

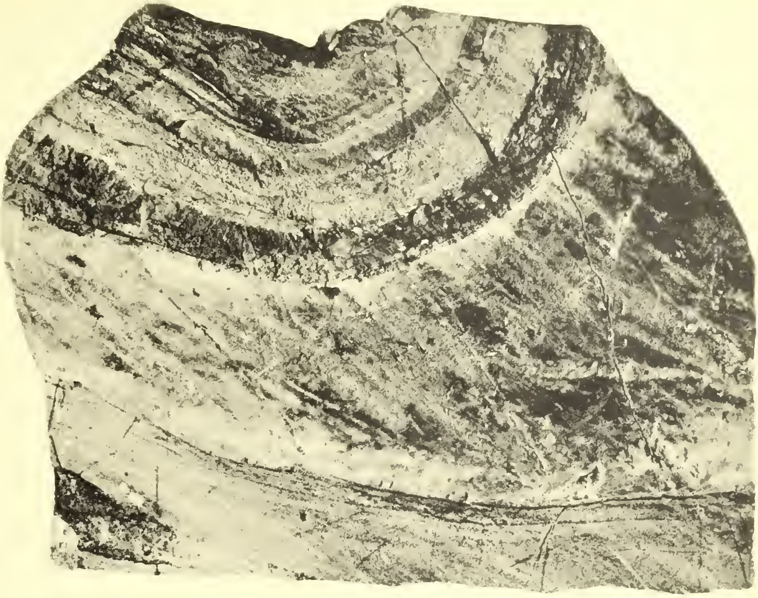
The data at hand for the determination of the succession of the rocks in the limestone series are very meager. The extremely disturbed condition of the rocks and the scarcity of fossils make a final interpretation of their age and structure at present impossible. The many cuts along the line of the Bangor and Aroostook Railroad give a better opportunity to determine the composition and position of the different beds than has heretofore been afforded.

Structure.—As seen in the field the limestone masses never present angles, but have their corners rounded off, and contain small sink holes in limited areas. The beds are very thin, usually from a fraction of an inch to a few inches in thickness, and rarely several feet. They are distorted and folded to an extreme degree along axes which run approximately northeast. The folds are at times 15 to 20 feet broad, but commonly are merely minute twists and plications, several of which may occur within a few feet. The apices of the folds are often enormously infolded and distorted on an almost microscopic scale. In one place thirteen complete miniature anticlines were counted, the total length of which was 9 inches from apex to apex, but was over 3 feet measured along the beds. In addition to the folds, there are countless faults, but always, so far as observed, on a small scale. Slickensides are formed in nearly every outcrop, and in places take the form of a succession of approximately parallel grooves along which movement has taken place. The grooves are now occupied by flattened columns of arenaceous limestone.

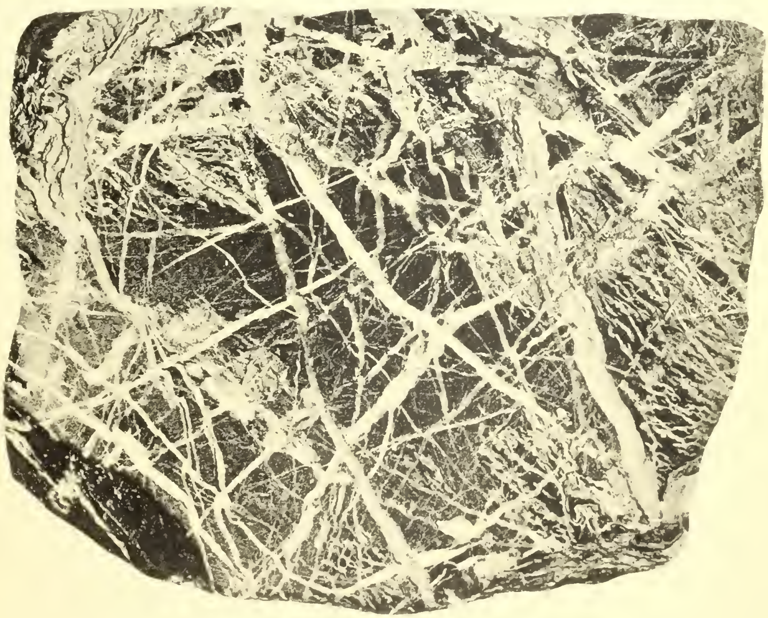
The average strike of the strata is about N. 60° E. in the southern part of the area, and N. 30° E. in the northern part. The dips are usually at high angles. Since folding has taken place the beds have been slated by planes running about northeast, which often nearly coincide with the bedding and are always more prominent than the bedding planes. Unusual caution is therefore required in taking measurements of dip and strike. Other sets of cleavage planes are present, and often serve to cut the strata into rhombs.

Petrography.—The exposed rock surfaces are coated with a thin, yellowish-white weathered zone. Owing to the varying amount of impurities in the beds the rock takes on a banded appearance, which is much intensified where metamorphism has been active. The rock itself is quite uniform throughout its whole extent and is of a typically grayish-black color, becoming a lighter gray in the more sandy beds. It is extremely dense, and under the highest powers reveals masses of exceedingly fine-grained calcite arranged in layers which vary slightly in size of grain. Quartz and fragments of mica and iron are also occasionally present.

Heavy beds of limestone.—Heavy beds of limestone, sometimes 10 feet and more in thickness, are found with the typical thin-bedded variety, especially between Presque Isle and Fort Fairfield and in the



(A)



(B)

(A) BANDED LIMESTONE.
(B) AROOSTOOK LIMESTONE.

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big limestone cuts on the Bangor and Aroostook Railroad between Ludlow and Ashland Junction. These heavy beds are not so closely folded, but the apices and troughs are altered to marble in places and the strata are broken into massive blocks. Generally speaking, the limestones in the vicinity of Houlton are more evenly slated, more arenaceous, and not so closely folded as in the Aroostook Valley.

The disturbances through which these rocks have passed seem to have destroyed the fossils to a large extent, for although diligently searched for at many places, the number of species found is remarkably small. (See Pls. X, XI for illustrations of Aroostook limestone.)

FOSSILIFEROUS LIMESTONE.[1]

Fossiliferous limestone is found in and near Ashland Village, at Dudley's in eastern Castle Hill, in the northwest corner of Chapman Township, and in the well-known Square Lake locality. In Ashland Village the rock is whitish brown, much broken and brecciated, and is practically composed of fossils in all stages, from complete forms to finely comminuted fragments. The field appearance is of a rough groundmass, irregularly broken into blocks. Two hundred feet to the south this brecciated material is overlain by regular beds of dark fossiliferous limestone conglomerate, which is here interbedded with shales containing rolled pebbles and nodules. The limestone beds are occasionally pinched out or occur as lenticles. South of the village the outcrop on the west of the road shows white limestone with abundant fossils, while east of the road, 1½ miles south of Ashland, the rock is a conglomerate, in which limestone, sandstone, and shale are promiscuously mingled.

The Castle Hill and Chapman occurrences are substantially alike, and only the former will be described. The outcrop is best exposed on Mr. Dudley's farms, near the house and on both sides of the road. Here the white limestone is embedded between slates which strike N. 40° E. and dip E. $< 70°$. The slates on one side are the ordinary calcareous slates of the region, but immediately adjoining the limestone on the west the slates are black and reddish, with heavy staining of hematite and manganese. The fossiliferous limestone here is dark gray, and fragmental material from various sources is mingled with the abundant fossils.

SLATES AND SCHISTS.

The Ashland branch of the Bangor and Aroostook Railroad crosses the strike of a series of slates and schists, and where cuts have been made furnishes good exposures for study. No detailed work has been done on these rocks, but a few general statements may be found useful.

[1]This limestone is named and described as the Ashland limestone in Part I of this report.

Near the bridge at Smyrna Mills the slates in general are steel-blue in color, and so fissile that they split into flakes as thin as paper. The slating is very regular in a plane which strikes N. 70° W., with a dip N. $<$ 80°. Another plane of cleavage runs N. 40° E. and cuts the slates into large blocks. Interbedded with slates are thicker black clay layers and thin beds of micaceous sandstone. In two cases the sandy beds are replaced by coarse indurated conglomerate containing large rounded fragments of quartz, black slate, and fine grits. Only rarely do these coarse layers extend for any distance, but are commonly pinched out between the other beds.

Along the track to the north of Smyrna Mills the slates are found to be much crumpled and distorted, and vary in color from green to gray, with occasional reddish layers. They all have a smooth surface, especially the green varieties, and the sandier layers are not prominent. In a cut south of milepost 117 are black slates with the steel-blue variety, having their bedding planes marked by a thick sprinkling of brilliant crystals of iron pyrites. The beds at this place strike N. 80° E., dip south at a high angle, and the cleavage runs east-west.

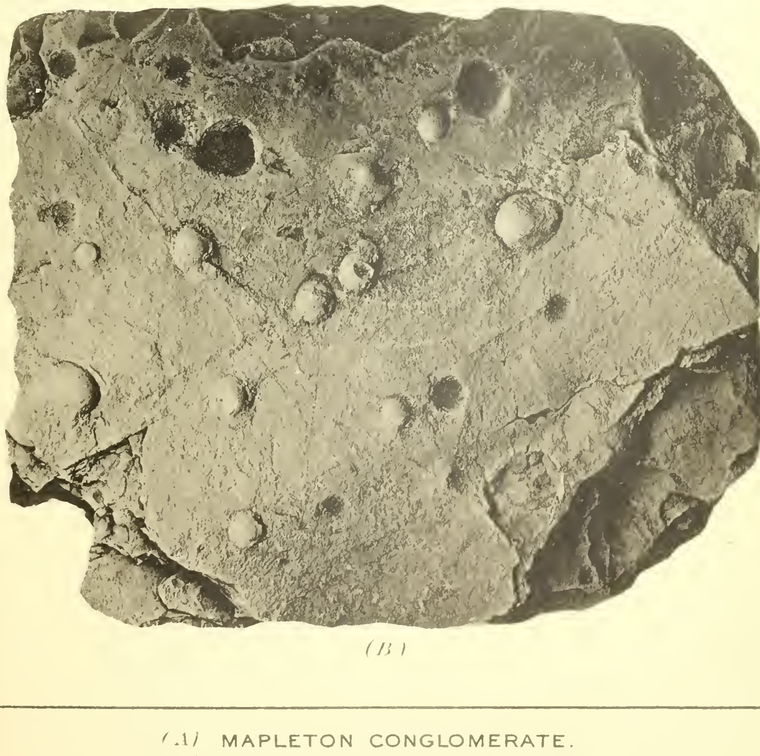
At Weeksboro, near the station, the slates are light gray, with very soft and greasy feel. They are folded, faulted, and twisted to an extreme degree, and show many small slickensides. The cracks are now filled with quartz, which indicates the amount and character of the distortion. All bedding and regular slating are here destroyed, and the rock breaks up into chips and irregular slabs.

Near St. Croix Station the slates approach more nearly the character of typical phyllites. They are here steel-blue in color, somewhat micaceous, and split regularly into very thin slabs which strike east-west and dip N. $<$ 80°. Thin beds of fine sandstone occur with the slates.

Northward from St. Croix the sandy layers become a more prominent member of the phyllite series, and at the Mill Seat on the St. Croix River the rocks are micaceous sandstones in beds 2 inches to 2 feet thick, interbedded with blue-black slates, which are very smooth and have a greasy feel. On weathering, all the rocks at this place assume a pure white appearance, like a smoothly finished plaster wall. The finer layers are largely composed of minute mica flakes. The beds strike N. 85° E. and dip N. $<$ 80°. One slaty cleavage is parallel with the bedding, while another prominent cleavage runs N. 20° E. and dips E. $<$ 70°, thus cutting the beds into rhombs.

At the "foot of dead water" on the St. Croix, in T. 9, R. 5, the rocks exposed are gritty slates with indistinct bedding. In the railroad cut at this locality the rocks show a number of broad folds with minute plications on the limbs, and the beds are stretched and pinched out in places. Embedded in these slates are two big bowlders of igneous rock to which the slates have adjusted themselves. It is thought

(A)



(B)

(A) MAPLETON CONGLOMERATE.
(B) MANGANIFEROUS IRON SLATE.

THE HELIOTYPE PRINTING CO. BOSTON.

that these bowlders may have been carried out in the Paleozoic sea by the ice and deposited as we now find them. The various cleavages found in the slates have not affected the igneous blocks.

The other outcrops found in this township, and also in Masardis, are sandy slates and fine micaceous or feldspathic sandstones, with occasionally a limestone bed. West of Masardis the beds are sparingly fossiliferous.

MANGANIFEROUS IRON SLATES.

In his second report Dr. Jackson[1] described at considerable length beds of "compact red hæmatite" found on the Aroostook River in what is now the southeast corner of Wade Township. The analysis made at that time showed 76.80 per cent of peroxide of iron, and the calculated amount of iron in sight at this outcrop was 97,200 tons, and a connection between this bed and the one near Woodstock, New Brunswick, was assumed.

Besides the locality described by Dr. Jackson, outcrops of this manganese-bearing iron slate were found on Dudley's farms, in southeast Castle Hill, and on the State road half a mile west of the Mapleton-Castle Hill line. Similar slates, containing less iron, occur also in Woodland and New Sweden. In all these cases the ore occurs as stains on slate, which is interbedded with the ordinary slated limestone of this region, and the ore varies in amount from a faint reddish stain to small areas of iron and manganese oxides quite free from calcareous and siliceous matter. In the Castle Hill outcrops the ore occurs as flattened pellets between the finely divided slate layers (see Pl. XII, *B*). The position of the five known outcrops of this slate is on a line which has nearly the direction of the general strike of the limestone.

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[1] Second Rept. on Geology of Public Lands, pp. 37 et seq.

CHAPTER IV.

PETROGRAPHY OF THE IGNEOUS ROCKS.

The igneous rocks of northeastern Maine show considerable varia tion in composition and are represented by members of most of th important rock families. Abyssal rocks are not prominently exposed and the number of dikes is relatively limited. The great bulk of th igneous occurrences are of well-marked extrusive lavas in a good stat of preservation. The types found in this region are for the most par well recognized, and the classification used will require no explanation Where this is not the case, the discussion of terms and variations wil be found in connection with the various rocks described.

The subject-matter will be treated in the following order:

Granites.—Mapleton granite; Drews Lake granite; dark aggregate in the Mapleton granite; dikes of the granite areas; metamorphisı caused by the granites and associated dikes.

Rhyolites.—Rock of the main mountain mass; white type; perliti type; rhyolite-breccia; vesicular lava.

Trachytes.—Hedgehog trachyte; trachyte of Chapman Townshi doubtful trachytes; Quoggy Joe quartz-trachyte; quartz-trachyte c township 9, range 3.

Andesites.—Augite-andesite; hornblende-andesite; andesites c southern Mapleton; andesites of Castle Hill; andesite ash beds.

Diabase.—Aroostook Falls diabase; Mars Hill diabase.

Teschenites.

GRANITES.

The two granite areas in this region are about 40 miles apart, an will be considered separately. While it seems best, from the gener nature of the rock forming them, to call these masses granite, atte tion must be directed to the variable character of the composition ar structure of the rock.

MAPLETON GRANITE.

The Mapleton granite is light gray in color, with a pinkish ting given by the larger feldspars. At first sight the grain seems ve coarse, but this appearance is caused by the presence of the larger fel spar crystals set in a medium-grained mass of dark and light mineral These feldspars might almost be designated phenocrysts. Parts

the rock are quite marked in their porphyritic tendency. In the hand specimen hornblende is seen to be the most common dark mineral, and titanite is visible to the unaided eye. None of the minerals, except feldspar, are longer than 3 to 4 millimeters. From this general type the rock passes within a few rods into pegmatitic facies on the one hand and into a fine-granular variety on the other. In places hornblende is practically the only dark mineral, elsewhere the rock appears to be an aggregate of mica. Sometimes quartz can not be seen in the hand specimen. So decided is the character of these variations that if they occurred as independent masses they would be classified as syenite, minette, etc. Numerous dark aggregates, such as are described in granites of other regions, occur throughout the mass. These, too, vary in the proportion and character of their component minerals.

In thin section, under the microscope, the Mapleton granite shows the following mineral composition: Iron ore, apatite, titanite, biotite, hornblende, oligoclase, orthoclase, including microcline, and quartz. The iron is mostly included in the hornblende. The apatite exhibits the usual negative laths. Titanite in well-developed idiomorphic crystals is more common than in most granites. Biotite occurs in good, clear, strongly pleochroic sections or in stringy and twisted strands entwined with chlorite. The hornblende, like the biotite, is partly developed as irregular masses, sometimes radially grown, and partly it is the normal brown-green, pleochroic variety. The oligoclase shows Carlsbad twinning, and measurements according to the Michel Lévy method indicate a composition of $Ab_8 An_1$. Orthoclase shows incipient kaolinization; zonal banding is conspicuous and the grains are sometimes broken. Microperthite intergrowths are well marked in places, and again are represented by a few albite strands in the orthoclase. The microcline exhibits the indistinct, partly developed character more fully described as occurring in the granite and dikes near Ludlow. Quartz grains are usually the broken pieces of larger grains and have the wavy extinction characteristic of quartzes subjected to pressure.

In structure these granites differ from the usual hypidiomorphic type. The quartz tends to be idiomorphic against the orthoclase, either by developing some crystal edge in the territory occupied by the feldspars or by sending branches into the side of the orthoclase crystals. In places several of the quartz areas extinguish simultaneously between crossed nicols. Throughout the whole section the feldspar boundaries tend to indefiniteness, and there is an approach to the conditions found in graphic granite.

The conditions of growth here indicated are different from those in ordinary deep-seated granitic rocks, and support the hypotheses founded on field observation. The porphyritic tendency is suggestive. The larger feldspars seem to have first formed as phenocrysts, since they

stand out against the groundmass with distinct outline; but some of the feldspars must have continued to form and develop later than, or simultaneously with, the quartz. The micrographic intergrowth indicates an enforced hastening of the cooling process. All these observations are in keeping with the idea that this is a small intruded mass whose present surface is probably not far from the original periphery. The presence of microcline, the numerous shattered grains of quartz, and the few broken feldspars all point to pressure on the mass after cooling.

Dark aggregates in the Mapleton granite.—These either take the form of a mass of mica shreds and plates, in which the quartz and feldspar is scarcely visible, or they appear as a thick sprinkling of hornblende, biotite, and titanite in an area of fine-grained, light-colored rock. They are a foot and less in diameter and are very irregular in outline.

An examination of thin sections under the microscope reveals an abundance of apatite columns, and especially needles. Some are as long as the mica laths and run through two or more minerals without a break. The titanite grains are eaten into and at times inclose other minerals. Biotite is strongly pleochroic and sometimes entwined with the hornblende. The hornblende is the brown-green variety, pleochroic, with good basal and prism sections, often grouped in masses and intergrown with or idiomorphic against the biotite. Some sections are bent. The feldspar, in small laths and irregular pieces, occupies bays in the hornblende, biotite, and titanite, or may even be idiomorphic against them. What little quartz is present shows a rolling extinction. It is instructive to note the similarity in composition between these dark aggregates and the kersantite dikes described below. It is as if a differentiation begun in the mass had reach reached completion in the associated dikes.

DREWS LAKE GRANITE.

The granite from the Ludlow quarry is considered typical for the Drews Lake district. It exhibits two well-marked varieties in different parts of the quarry. The highest rock exposed by the workmen has a grayish-white color in the hand specimen and its surface is sprinkled inconspicuously with dark specks. Quartz shows prominently and often forms aggregates of considerable size. In the bottom of the quarry the granite becomes a dark-gray variety in which the dark components assume a leading rôle and quartz is scarcely noticeable in microscopic examination. Transitions occur between these two types. While the rock differs thus widely in the relative distribution of mineral constituents, it retains a medium-grained, uniform texture, and the specimens at hand show no porphyritic tendency.

Under the microscope the granite from Ludlow differs from that from Mapleton in having the iron ore often in bundles of rods within the biotite, in the absence of titanite, and in the presence of a little

zircon. The microcline here and in the quartz-porphyry dikes of this district is worthy of special consideration. It is abundant, and is sometimes partly idiomorphic and distinct in character, but usually is not a clear-cut type and is connected with orthoclase as part, or nearly all, of a crystal section with no distinct line of demarcation. Sometimes it is intergrown with orthoclase and has distinct boundaries between the two minerals (see fig. 9). The structure of this granite shows the same characteristics as the Mapleton outcrop previously described.

The term granite is applied to these northern Maine rocks as being the nearest approach to the average of the typical exposures. Quartz is so often present in small amount and hornblende is so conspicuous that they might be more accurately termed hornblende-granite-syenite.

DIKES OF THE GRANITE AREAS.

Aplite occurs both on the Aroostook River and at Ludlow without characteristics peculiar to either locality. The rock is grayish white,

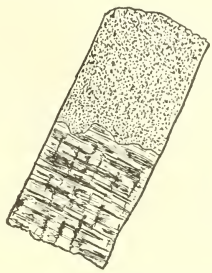


Fig. 9.—Microcline and orthoclase intergrowth.

smooth, and dense. The only minerals apparent to the unaided eye are pyrite and an occasional feldspar which has attained a somewhat larger size than its fellows. Closer examination shows that the rare dark mineral is usually hornblende, that orthoclase constitutes nearly all the feldspar, and that the remainder is oligoclase in well-developed crystal sections with Carlsbad twinning. The quartz takes its usual place as a cement and has a rolling extinction. Little areas of separate quartz grains extinguish simultaneously when revolved with cross nicols. The rock is seen to consist essentially of quartz and orthoclase and tends to a sugar granular structure, and hence is classed as an aplite.

Syenite, as reported by Professor Bailey,[1] is found in a dike in the bed of the Aroostook at the base of the hill formed of the Mapleton granite. The rock is light gray and fairly fine grained. The dark components are collected in small bunches instead of being evenly spread throughout the more abundant whiter minerals. The rock is practically quartz-free and has the characteristics of an ordinary syenite, being composed of orthoclase, oligoclase, biotite, and horn-

[1] Bailey, Ann. Rept. Geol. Nat. Hist. Survey Canada, 1887-88, Pt. M, p. 46.

blende, with an abundance of pyrite. In composition and structure this rock seems intermediate between the aplite mentioned above and the kersantite to be described later.

Granite-porphyry.—In the railroad cuts immediately east of Ludlow the sedimentary rocks are cut by two classes of dikes. The first class includes the aplites, and the second class consists of three narrow dikes—10 feet, 30 feet, and 60 feet wide—of a distinct type of granite-porphyry. In the hand specimen the rock appears as a mixture of pepper and salt in about equal proportions, in which white feldspar crystals have been set. These prominent phenocrysts are not crowded together in any part of the dikes, and usually they are separated by as much as their own width. No other mineral rises in size above the general groundmass. Microscopic examination of a thin section reveals the presence of biotite, hornblende, oligoclase, orthoclase, microcline, and quartz, with accessory iron, apatite in many minute hairlike crystals, zircon, and titanite. Biotite is mostly in shreds or laths with ragged edges, or in clusters and bunches, either of mica alone or

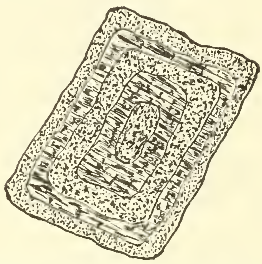


Fig. 10.—Zonal intergrowth of microcline and orthoclase.

entwined with hornblende. One agglomerate composed of from twenty to thirty pieces of biotite is twisted and knotted together like cords. Little loose strings of biotite are found which appear to have been torn off from larger pieces. The hornblende is the common green variety, strongly pleochroic, and occurs in short laths or in irregular stringy sections. The oligoclase presents nothing of special interest. Orthoclase, both as phenocrysts and in the groundmass, occurs as well formed laths, simple or twinned according to the Carlsbad law. The larger sections especially are altered at the center to kaolin. White mica is also found along the cleavages as an alteration product. Microcline occurs in indefinite, partly developed structures in connection with orthoclase, and also as clear-cut crystal sections, with the characteristic cross hatching clearly defined. With the orthoclase it forms peculiar zonal growths. The outside of a microcline section may be separated from the inside by a zone of orthoclase; or the microcline may be completely surrounded by a band of orthoclase. In one case four zones—two orthoclase and two microcline—must be passed over in going from the periphery to the center of the crystal (see fig. 10).

Quartz is in larger grains than any other mineral except the feldspar, but also occurs in small grains in the groundmass. It has rolling extinctions and is muddied by inclusions.

Kersantite.—This rock is found only in connection with the Mapleton granite area where it outcrops in the river in two dikes. One of these is small, the other is 500 feet or more wide. It appears as a very dark, stone-gray, cryptocrystalline rock with glistening surface. So far as can be seen without the microscope, the texture is uniform. When examined under the microscope a thin section shows the presence of iron ore, abundant apatite, biotite, hornblende, plagioclase, orthoclase, and quartz. Biotite is ragged and stringy, usually grouped in irregular masses, and largely altered to chlorite. The hornblende is also mostly changed to chlorite and is not abundant. The plagioclase is oligoclase-andesine with the formula Ab_3An_1, as shown in its extinction angles in Carlsbads by the Michel Lévy method. Orthoclase is in almost square laths; a few show twinning. The feldspars are much altered and eaten into, the cavities now filled with calcite. The structure is dense granitic, verging toward porphyritic from the development of some plagioclase larger than the average.

This rock has the characteristic lamprophyric appearance, and this, taken in connection with the excess of plagioclase over orthoclase and the abundant mica, shows it to be a typical kersantite.

METAMORPHISM CAUSED BY THE GRANITES AND ASSOCIATED DIKES.

Mapleton area.—The Aroostook River, where it flows through the townships of Washburn, Mapleton, and Presque Isle, gives a good section through the region affected by the Mapleton granite area. The outcrops along the river east of Washburn Ferry show the general country rock to be a black arenaceous limestone, thin-bedded, and alternating with beds of gritty material which under the microscope proves to be composed largely of broken pieces of quartz, feldspars, and calcite. Following the river downstream, the first marked change in the character of the rock is seen where it occurs between a dike of aplite and one of syenite. Metamorphism has here produced a compact schist of a grayish-green hue, prettily marked by a multitude of fine bands and lines of various shades of gray, representing the bedding planes in the old shale. The rock is so cut through by intersecting cleavages that only hand specimens can be removed. The acid test shows a very little lime, mostly in the white bands. With the aid of the microscope we find the main mass composed of lime garnet (grossularite), some pyroxene, calcite in bunches, and a little quartz and iron in a background of feldspar. This corresponds very well with the expected metamorphic changes in the gritty layers of the country rock. Side by side with this banded schist we find layers of impure marble which may represent the more limy parts of the general slates. Farther

down the river, between the two large kersantite dikes, is a considerable area occupied by an impure, partly crystalline limestone with lead color and conchoidal fracture. It gives the appearance of having been brecciated on a fine scale and recemented. The microscope shows its composition to be in the main calcite, quartz, and grossularite. A short distance below this outcrop the immediate effects of the dike intrusions disappear.

The rocks adjoining the Mapleton granite are metamorphosed within a radius of about a mile to the southwest. The bedding of the original siliceous material is retained and can be easily traced for a considerable distance. The rock itself, however, has been converted into a tough, dense hornstone with conchoidal and splintery fracture. It is usually black, but at times it takes on a mottled gray color. In weathering a distinct white zone is produced, which is sharply marked off from the inside, as is common in felsitic rocks. The facts obtained from a microscopic examination show its metamorphic character and substantiate the observations made in the field. The sort of metamorphism here expressed and the general field relations lead to the conclusion that these hornstones are the unremoved remnant of the granite cover which on Munson's farm has entirely disappeared.

Drews Lake area.—The metamorphic rocks about Ludlow have not been studied in detail, but a few general observations may be made. Throughout the township of New Limerick metamorphic action has produced a hard schist marked by bands usually less than an inch wide which indicate the original bedding of the rock. The strike is several degrees more easterly than in the case of the less altered rocks to the north and east, and the dip is practically vertical. The banded appearance is produced, in the outcrops examined, by four layers: (1) a very hard, dark-blue, impure limestone, which sometimes attains a thickness of several feet; (2) a whitish siliceous limestone; (3) a hardened, black, micaceous slate; (4) a reddish layer of extremely fine, micaceous sandstone. This last layer is not very common. At Drews Lake more excessive local metamorphism has produced garnetiferous schists, and in one case a bed of saccharoidal limestone containing crystals of pyrite. The intrusion of many smaller dikes and the metamorphism caused by sharp folding of the calcareous strata still further complicate the structure in this region, and it is planned to devote more attention to it at another time.

RHYOLITES.

The rhyolites exhibited at Haystack, although covering so small a territory, exhibit great variation in composition and structure.

ROCK OF THE MAIN MOUNTAIN MASS.

Macroscopic description.—The rock forming the main mountain mass appears in the hand specimen as an exceedingly dense material of uniform texture, having a dark-gray color with a greenish tinge. It is just such a rock as has been called felsite in this region as a field term. Under the hammer it breaks in splinters and chips having sharp, jagged edges. It breaks much more easily in some directions than in others and reveals the presence of numerous shearing planes along which there has been a slight movement in more than one direction. These small planes can usually be traced but a few inches and are located so irregularly that it is difficult to find a flat even surface of more than a square inch in area. This character is markedly different from the Mount Kineo quartz-porphyry, which macroscopically it otherwise closely resembles. The more weathered material assumes a darker hue and is specked with black dots, which on microscopic examination are found to be alteration surrounding minute quartz aggregates. Occasional larger cavities occur which contain quartz crystals whose pyramid and prism faces are visible to the unaided eye. In weathering the rock forms a thin skin of rusty-brown material separated from the unaltered portion by a distinct boundary.

Microscopic description.—Under the microscope a thin section appears at first sight as a porphyry of broken quartz phenocrysts in a groundmass of feldspar. Both the quartz grains and the groundmass, however, present peculiarities worthy of consideration. The quartzes are not true phenocrysts, as the following facts show. Although occasionally there is a small individual quartz grain located by itself, there are usually five to fifteen closely interlocking grains occupying an area in the groundmass. The larger quartz grains are nearer the center of the aggregate, while the smaller are found about the edge and adjust themselves to the shape of the cavity by filling in the recesses with smaller and smaller grains. Tongues and veinlets of quartz project into the groundmass, filling the little cracks which are sparingly distributed throughout the section, but no included fragments are found in the quartz, nor are reentrant bays and corroded borders seen. The liquid inclusions in the quartz are not evenly distributed, but form lines and cusps and polygons, leaving part of the grain clear. These geometric forms are complete within the individual grains and are not broken at the contact between two grains of the aggregate, as would be expected if one were dealing with inclusions of a phenocryst which had been shattered into fragments. Furthermore, the quartzes do not show the wavy extinction characteristic of rock subjected to great strain. These facts point to a secondary filling of amygdaloidal cavities, and the supposition is strengthened by the

absence of areas about the quartz aggregates which are controlled by them in their optical orientation. The group of quartz grains themselves have no collective optical orientation.

Many of the quartzes are marked by a rude rhombohedral cleavage such as has been described by Clements.[1] It is quite possible that the rhombohedral cleavage of quartz in some rock sections is formed in the preparation of the slide. Feldspars often have their cleavage cracks enlarged by grinding, and occasionally a slide shows part or all of a crystal torn away. Quartz can be made to cleave by the pressure of a sharp point on thin sections,[2] and in the sections of Maine rocks it is noticeable that the thicker quartzes have no cleavages developed.

The groundmass is composed of feldspar and quartz, with a little chlorite that is considered as replacing biotite. No other ferromagnesian minerals are present. The feldspars, with plagioclase apparently predominating, occur almost altogether as short, narrow laths of irregular outline that are arranged without order or tend sometimes to form radiate groups and flow structures. They never show a tendency to become phenocrysts. Between crossed nicols the whole groundmass is seen to be divided into patches which extinguish as a unit and then lighten as the stage revolves. It is evident that this is due to a micropoikilitic structure, but one which presents some variation from the usual type. The groundmass is of quartz, clear or with inclusions, which are arranged in areas with rude mesh structure. Within this groundmass the irregular laths of feldspar lie embedded without uniform orientation, though often many neighboring individuals extinguish alike. The quartz areas have no regularity of shape or position or size, but extend in all directions, with recesses and elongated branches. The different quartz areas are connected by cross branches or bridged over by feldspar laths, and as the stage revolves one may trace a crooked course following the quartz between the little rafts of feldspar across the entire section. This structure is seen in ordinary light, but much better between nicols, especially when the quartz is so cut as to show its basal section.

Micropoikilitic groundmasses with similar structure have been recently described in rocks of a related character from Michigan and California.[3] The Michigamme rock which was first described is a quartz-porphyry whose groundmass is almost identical with that of the rock from Maine, except that in the latter practically all of the feldspars are laths. The California (San Clemente Island) rock is a dacite and

[1] J. Morgan Clements, The volcanics of the Michigamme district of Michigan: Jour. Geol., Vol. III, No. 7, 1895, p. 814.

[2] Mallard, Sur les clivages du quartz: Bull. Soc. min. de France, Vol. XIII, 1890, p. 61.

[3] J. Morgan Clements, op. cit., p. 814. W. S. T. Smith, Geological sketch of San Clemente Island (California): Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. II, 1898, p. 484. See, also, Geology of Santa Catalina Island (California): Proc. California Acad. Nat. Sci., 3d series, Vol. I, No. 1, Feb., 1897, p. 24.

shows a more uniform orientation of the feldspars than was observed in the other two. The characteristic features of this variety of the micropoikilitic structure are, feldspar laths embedded in a base of quartz, quartz roughly grouped into areas which extinguish simultaneously, and, within these quartz areas, the feldspar fragments without uniform optical orientation. If further study shows this structure to be of wider distribution an appropriate variety name might be useful.

Analysis.—The following analysis (I) of the rock forming the main mass of the mountain has been made by Dr. W. F. Hillebrand, of the United States Geological Survey:

Analyses of rhyolites.

Constituent.	I.	II.	III.	IV.	V.	VI.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	75.98	75.69	74.90	75.20	75.31	77.28
Al_2O_3	12.34	12.26	13.64	12.96	12.96	11.24
Fe_2O_3	.85		.66	.37	3.05	1.74
FeO	.93	2.93	.50	.27		None.
MgO	.15		Trace.	.12		.21
CaO	.13	1.13	.61	.29		Trace.
Na_2O	4.02	3.01	4.22	2.02	5.11	3.10
K_2O	4.44	4.74	4.64	8.38	3.15	4.55
$H_2O-105°$	.24	}	.33	.58	.61	1.16
$H_2O+105°$	.64	}				
TiO_2	.17		.15		.41	Trace.
ZrO_2	.03					
Cr_2O_3	?					
V_2O_3	?					
NiO	None.					
MnO	Trace?		Trace.	.03		
BaO	.07					
SrO	Trace?					
Li_2O	Trace?		Trace.			
P_2O_5	.03	.06		Trace.	.05	.02
CO_2	None.					
Cl	?					
Fl	?					
FeS_2	None.					
Total	100.02	99.82	99.65	100.22	100.65	99.47

I. Rhyolite, Haystack Mountain, Maine. Analysis by W. F. Hillebrand, United States Geological Survey.

II. Rhyolite, Rescue Canyon, Nevada. Analysis by R. W. Mahan. Hague, Geology of Eureka district: Mon. United States Geological Survey, Vol. XX, p. 264.

III. Rhyolite, Castle Mountain, Montana. Analysis by L. V. Pirrson. Weed and Pirrson, Geology of Castle Mountain mining district: Bull. United States Geological Survey No. 139, p. 120.
IV. Rhyolite, Round Mountain, Colorado. Analysis by L. G. Eakins. Cross, Geology of Silver Cliff and Rosita Hills: Seventeenth Ann. Rept. United States Geological Survey, Part II, p. 324.
V. Aporhyolite (Laminated orthofelsite), South Mountain, Pennsylvania. Analysis by F. A. Genth. Second Pennsylvania Geological Survey, Vol. CCC, p. 265. Recognized as aporhyolite by F. Bascom, Bull. United States Geological Survey No. 136.
VI. Aporhyolite, Fox Islands, Maine. Analysis by E. W. Magruder and W. A. Jones. G. O. Smith, Geology of Fox Islands, Maine. Presented as thesis at Johns Hopkins University; printed privately.

The analysis (I) shows the Haystack rock to belong to the alkaline series of rhyolites, and a comparison with the other analyses presented (II–VI) shows it to differ in no important particular from typical modern and ancient rhyolites of other regions. As the microscopic examination indicated, the components present must be practically quartz and alkali feldspar. The percentages of the different minerals have been calculated from the analysis as follows:

Mineral.	Per cent.
Quartz	34.1
Orthoclase	26.2
Albite	34.1
Chlorite	2.7
Kaolin	4.
Titanite	.4
Other minerals	.5
Total	100

WHITE TYPE.

Near the base of the hill the rhyolite, while retaining the felsitic appearance of the main mass, becomes white in color and does not break into such keen-edged chips. The quartz aggregates filling the flattened cavities are easily seen in the hand specimen. The weathered rock is yellow-brown and shows numerous narrow, troughlike cavities, at times becoming a quarter of an inch long and lined with small quartz crystals of secondary origin.

The microscope reveals a structure of the same character as that found in the rock from the top of the hill. There are no phenocrysts of feldspar, and the pseudophenocrysts present are formed of aggregates of from 10 to 20 quartz grains, each of which retains its crystal outline in some degree. As a rule, these aggregates have a large piece at the center, occupying perhaps one-half the space, and this piece is surrounded by smaller pieces, while still smaller fragments fill the irregular spaces next the cavity wall. The boundaries between the quartz grains are clear-cut lines, which often project into each other

by sharp angles. Usually two or more pieces situated near each other extinguish together. The groundmass is of quartz and feldspar, with the type of micropoikilitic structure described above.

The light-colored rhyolite at times takes on a peculiar structure, which is well brought out in weathered specimens. The vesicular cavities take the form of narrow tubes 1 to 3 inches long, all of which run parallel, the parallelism presumably having been caused by the flow of the rock, whereby the vesicles have been drawn out into long canals. When the rock is broken, so as to give a cross section of the tubes, the appearance is strikingly like that of a cross section through an endogenous plant, which shows the fibrovascular bundles arranged without order. The longitudinal section, however, exhibits long, narrow slits or troughs, sometimes lined with secondary quartz crystals, which give the appearance of birch bark. The color and the selective effects of weathering make the likeness still more evident (see Pl. VI).

PERLITIC TYPE.

Within the space of an inch the white aporhyolite is replaced by a rock of an entirely different type—one which macroscopically appears like perlite. Neither in the hand specimen nor under the microscope does the contact zone show any sudden change from one facies to the other, and it almost seems as if the whole effect was due to weathering, and yet the rocks are entirely distinct in structure.

Macroscopic description.—Examination of the hand specimen reveals a mass of spheres 1 to 5 millimeters in diameter, composed of a grayish-green substance with interstices filled with the same material. In the fresher parts the spheres remain in the mass and are broken across by a fracture of the rock, revealing centers filled with a shining green-black substance. Where the rock is more weathered the spheres are loosened and readily drop out. When a thin section is viewed without the aid of a microscope the spherule structure is clearly seen, especially when brought out by weathering. The spheres—not always round in section—are bounded by a brown glassy substance, and the interspaces are seen not to differ in appearance from the material forming the spheres except that they are more altered. The centers of the spheres often contain quartz grains and an area made up of chlorite and delessite (see Pls. V, *A* and XIII, *A*).

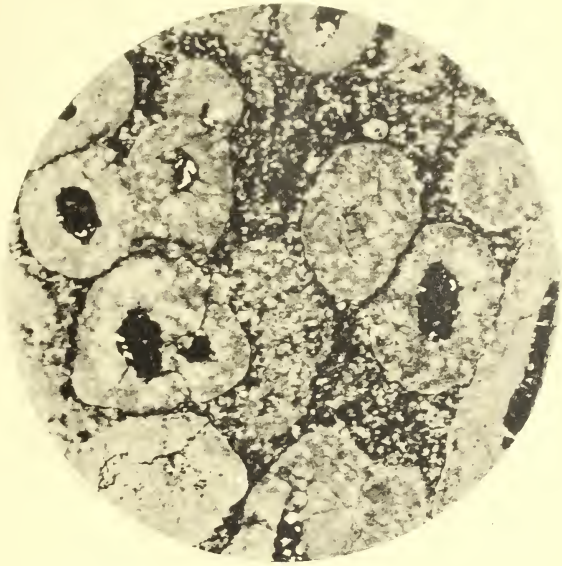
Microscopic description.—Microscopically examined, the thin section reveals no smaller spheres than were seen with the naked eye. The centers of the spheres are found to be oblong or elliptical cavities wholly or in part filled as follows: A few quartz grains showing crystal outlines and marked by inclusions and a rude rhombohedral cleavage project into the cavity. Surrounding the quartzes as a fringe, and extending as a zone all around the cavity, is found a brownish-green mineral, probably delessite. The center of the cavity is filled

with chlorite in bundles and radial growths. Combinations of chlorite and delessite form beautiful rosettes and colored vermiculate bodies. Limonite is also present in formless masses. The alteration products so well exhibited in the cavities are distributed as dots and little masses more or less abundantly throughout the section.

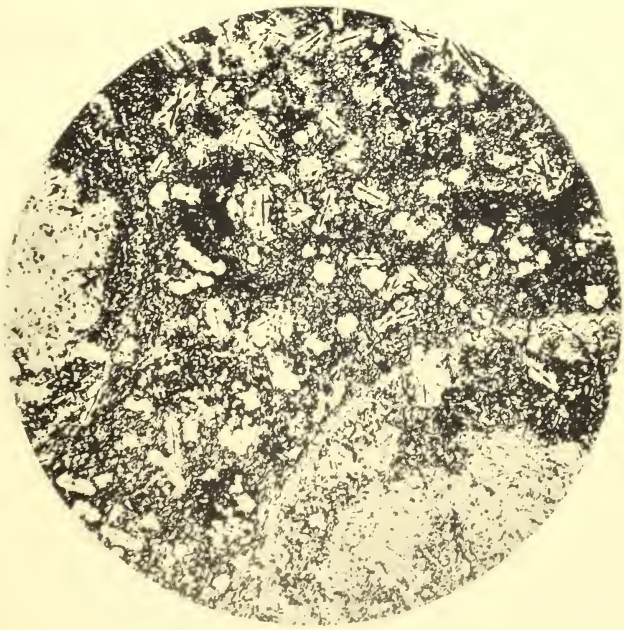
The groundmass is glassy. In places it is entirely amorphous; elsewhere minute feldspar laths lie in an undifferentiated background, and in still other places the feldspars lie in small areas of quartz with a structure which approaches the micropoikilitic. The glassy groundmass is crowded with crystallites which assume ordinarily rodlike or needlelike forms, but which also occur branched or crossed, and in rare instances form a radial structure resembling the spokes of a wheel. Around each of these crystallike bodies is a colorless zone, indicating that the rodlike growth has been built up at the expense of the surrounding part. The substance which composes the rod and the dark parts outside the colorless zone is of the same composition. In the section examined this material is found to be largely chlorite, but from the shape of the rods and the character of the alteration it is judged to have been mostly biotite. The clear zone surrounding the crystallites appears in ordinary light as a light-yellow glass from which the dark components have been absorbed to make the center rod. Between nicols the glass is found to be partly devitrified, revealing numerous little feldspar laths in the glassy base. It is evident that the rock section presents the same general appearance under the microscope as when fresh and that it is made up of grains and partly formed crystals of ferromagnesian minerals in a vitreous groundmass. The minerals have altered in composition and the glass is in part devitrified, but the type of structure remains unchanged. The appearance of the rodlike bodies surrounded by a clear space is seen only in ordinary light. In polarized light nothing appears except the feldspars in their quartzose and glassy base. The accompanying figure (Pl. XIII, *B*) will illustrate the points discussed above.

RHYOLITE BRECCIA.

Macroscopic description.—Near the southeast base of Haystack, on the north side of a slight rise of ground, a few small masses of porphyritic breccia are found. The hand specimen shows a greenish-black rock with small, waxy-looking feldspar phenocrysts, which differ little in color from the main groundmass, but are noticeable for their lustrous reflection on cleavage surfaces. Distributed thickly through the porphyry are irregular angular fragments of a pitchstone, which at times are as large as 3 to 4 inches in diameter. For the most part these glassy chunks have an oily-looking surface of various shades of dark green. They are much cut up by a series of fractures, so that under the hammer they are broken into little irregular chips. At times the pitchstone assumes various shades of red.



(A)



(B)

(A) PERLITIC TYPE OF RHYOLITE.
(B) AREA BETWEEN SPHERULES, PERLITIC TYPE OF RHYOLITE.

Microscopic description.—The microscope brings out the porphyritic structure well and reveals the presence of phenocrysts of orthoclase and oligoclase. Quartz and an undetermined mineral are present and rise in size above the general groundmass. Apatite occurs in long needles, which are broken and thrown out of alignment. The groundmass varies in character with the fragments of the breccia. The orthoclase phenocrysts occur as plain laths of a somewhat square shape or as twins or basal sections nearly always with good crystal outlines, but they also occur with rounded edges or inclosed by a distinct zone of alteration. The oligoclase phenocrysts are fewer in number than the orthoclase, but exhibit the same general features. The feldspars measure 2 to 5 millimeters in length and are broken along lines where the pressure has been relieved. Alteration to kaolin and sericite has progressed so far that no clear pieces remain. Another mineral about one-fourth the size of the feldspar phenocrysts is abundant in the slide in limited areas. It is yellow-brown in color where freshest, but changes with different stages of alteration to a lavender-gray. Its shape and cleavage suggest a tetragonal mineral, and the high colors shown by double and single refraction suggest one of the rare accessory minerals—rutile, zircon, or cassiterite. The polarization is given by an aggregate of grains, and the present altered state makes accurate determination impossible. The chunks of rhyolite pitchstone embedded in the mass yield a small amount of water in the closed tube and show a partially devitrified structure under the microscope. Small aggregates of quartz grains, now occupy areas and cracks which appear to have been cavities that were filled by the quartz at a later date.

Some fragments of the breccia have a groundmass composed of quartz and feldspar grains and laths arranged in well-developed flow structure. The streams separate to flow around the phenocrysts, then reunite beyond. Other portions of the breccia show a considerable portion of partly devitrified glass in their groundmass, especially when the section is cut through the included glass fragments seen so prominently in the hand specimen. In one place a group of lathlike feldspar phenocrysts is found with the interstices occupied by altered glass, thus imitating the structure found in some diabases and termed mesastasis by Rosenbusch. Chlorite is now an abundant secondary product throughout the whole rock.

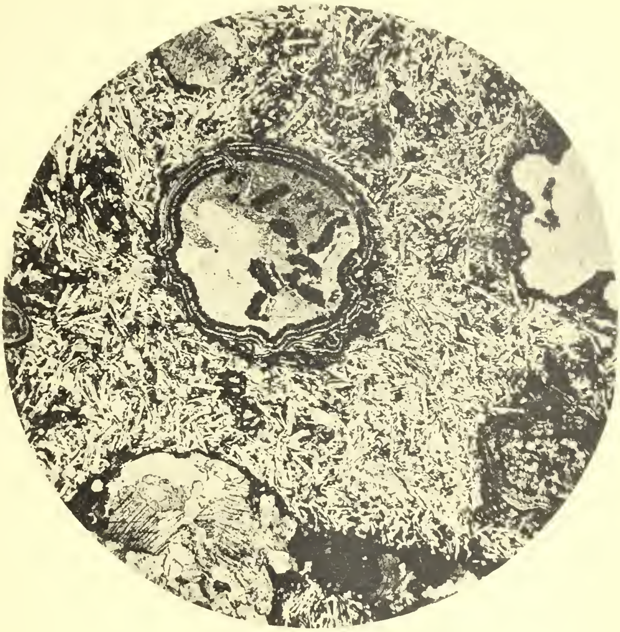
VESICULAR LAVA.

About three-fourths of a mile east of Haystack are a few scattered hummocks of coarsely vesicular lava. The surface exposure is of a rusty yellow rock, from which project angular knobs formed by weathering along the cleavage cracks. These cleavages are very numerous and intersect at all angles.

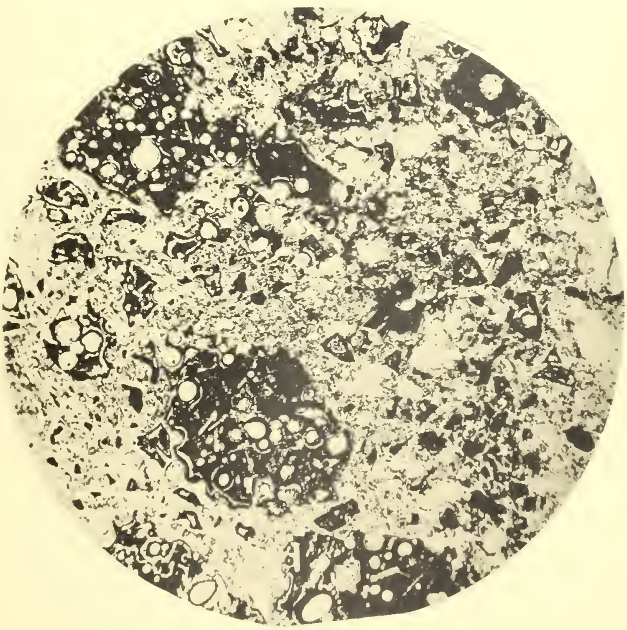
Macroscopic description.—When a hand specimen is broken from the ledge, attention is at once called to its spongy appearance, which suggests furnace slag coated with iron rust. This porosity is caused by the presence of cavities which average about 1 millimeter and are so numerous as to form nearly half of the rock. Examination of fresher material shows that it has an ashy-gray color and dense texture, and that the oval cavities which in the surface exposure were empty are here filled with black and white calcite. The cleavage cracks are also filled with calcite. These vesicles may be so broken as to show in cross section, or they may retain their identity and remain on the surface as projecting spheres (see Pl. V, *B*).

Microscopic description.—When a thin section is studied the vesicles present the most prominent appearance. They are ½ to 3 millimeters in diameter. The smaller ones are usually round, others are oblong, while many have a wavy outline formed by several neighboring bubbles whose inside division walls have been broken down. The boundary of the cavity is marked by a dense substance, probably a glass blackened by ferritic material, and the cavities are lined with a layer of impure fibrous calcite, which may be a mere film or may fill half the space. Three or more concentric layers may form the lining, and one or more of them may bulge out to form little bays. The lining is often broken, and fragments have become entirely detached and drop in toward the center. Sometimes the cavity is half, or even entirely, filled with these fragments. Areas are found where the single cavities are replaced by a group of minute vesicles which have a definite boundary. These cavities are now entirely filled with calcite. The feldspar laths of the groundmass are crowded together and arranged in a rudely concentric manner about the vesicles. The form and structure of these cavities are shown in Pl. XIV, *B*, and are explained as follows: The water contained in the rock was driven out by the crystallization of the magma and was free to act mechanically as steam. Centers of accumulated steam formed the cavities and have left the feldspars in their wreath arrangement. The lining of one or more concentric layers of impure iron and lime compounds was then formed. Some slight jar then produced the few cracks and broke down the lining of the tiny geodes. The rock shows no effects of outside strain except these broken vesicles, and the effects just mentioned may be due to the action of the solution within the cavity itself. Finally, infiltrated calcite has filled all the broken cavities and cracks, and is the most prominent mineral seen under the microscope as well as in the hand specimen.

The general groundmass is trachytic, and is composed of quartz grains and feldspars with a few large apatites. The feldspars are apparently about half plagioclase and half orthoclase, and occur mostly in delicate shreds, sometimes thirty times as long as broad. The ends



(A)



(B)

(A) VESICULAR LAVA.
(B) VOLCANIC TUFF.

are split and uneven and at times become merely a bundle of fibers, while little branch threads cling to the sides of the shreds. Sometimes straight feldspars are seen, but more often they are bent or curved so much as to form a half circle. Besides the expansion structure so well exhibited about the vesicular cavities, parts of the slide show a well-developed flow structure. The rock is plainly a vesicular rhyolite lava with dacitic facies.

TRACHYTES.

Under this head will be described all the rocks of this region whose principal component is alkali feldspar, whether they occur as extrusive volcanics or as intrusive masses or dikes. For the purposes of this discussion they will be grouped as trachytes, doubtful trachytes, and quartz-trachytes.

HEDGEHOG TRACHYTE.

The specimens of this rock found in place are all from the cliffs and sharp comb at the very highest points on the mountain, but there is reason to believe that they fairly represent the whole mass. When seen in the ledge the rock appears as rough tabular blocks formed by intersecting cleavages. The color is very light gray on the more exposed surfaces and a rusty iron brown in the narrow cracks, but a blow of the hammer shows that this outer weathering is scarcely thicker than a coat of paint, and that the fresh rock is bluish gray in color, with a mottled appearance. The general texture is fine, uniform, not at all porphyritic, and, at one point on the mountain, slightly brecciated. The whole rock, however, contains abundant vesicular cavities, round or oval in shape, and varying in size from a pin head to a quarter of an inch in diameter. These cavities are usually filled with quartz, occasionally of the amethyst variety, and some contain a glistening white calcite. The rock is now thoroughly silicified, and the cavities and minute cleavages and fissures are filled with firm cement that in weathering melts down only as fast as the original material, or even more slowly, so that occasionally a quartz-filled veinlet projects slightly above the general level of the weathered surface. The rare empty cavities found in the altered portions were probably filled with calcite.

The microscope reveals a rock made up of quartz-filled vesicles in a groundmass of feldspar laths. The quartz filling the cavities is composed of many grains, jagged and branched, with no optical orientation as a group, and only rarely containing inclusions. The minute fissures are filled in the same manner, and all the facts point to a secondary origin of the quartz. The sections of feldspar shown in the slide vary in form from long, rodlike shapes to squares, but the greater number

occur as rectangles three or four times as long as broad, which present clear-cut outlines and do not show the ragged, stringy, thunderbolt forms found in the Chapman trachyte and the andesite from Edmunds Hill. No dark-colored mineral appears in the rock, and the chlorite present in considerable amount gives no clue as to the mineral it has replaced. The groundmass is arranged with remarkably good flow structure. Practically all the feldspar microlites are arranged with their longer axes parallel, and the streams which they form are seen to divide in order to pass around the quartz-filled vesicles and then to reunite beyond. The section examined contains a fragment of a somewhat different igneous rock, which, judging from the manner in which the lava has flowed about it, appears to have been dropped into the lava flow while in motion.

TRACHYTE OF CHAPMAN TOWNSHIP.

Macroscopic description.—When seen in the ledge the appearance of this rock is very deceptive. It has there a brownish-black color, smooth feel, and presents little tables with angular outlines rather than round-cornered fragments. However, when the rock is broken, so as to expose fresh material, the brown color and smooth feel are seen to be confined to a very thin layer on the outside, while the main mass has a very light-gray color with a bluish cast and a rough feel, and breaks into sharp, irregular chips. In general the rock is dense and uniform and specked with minute black dots, which at times are large enough to be distinguished as cavities with black lining. Feldspar crystals, stout, or more often long and very narrow, are scattered inconspicuously through the mass, and would be scarcely noticeable except for their glistening cleavage faces. The whole rock is marked by numerous slits or flat, slender cavities, short and small, but sometimes half an inch in length. Their longer axes are parallel to one another and approximately horizontal. These slits represent the cavities of a highly vesicular lava which have been drawn out from their spherical shape by movements of flow.

The cavities are now usually empty, being only lined with a rusty-yellow substance, but some of the larger ones are filled with calcite or quartz. So distinctly trachytic is the rock in its general appearance and decided flow character that from an examination of the hand specimen alone one feels safe in designating it a feldspathic lava.

Microscopic description.—Under the microscope a few feldspar phenocrysts and patches of chlorite are seen to lie in a groundmass of feldspar laths. Quartz is also present. The larger feldspars are so cut in the section as to show squares, or, more often, narrow laths half a millimeter long. Carlsbad twinning occurs with irregular division line between the two halves, and from this line tongues of one twin

project to a considerable distance into the other. One section shows a partly developed microperthite intergrowth. All these larger unstriated feldspars are of the clear sanidine variety and have much the appearance of quartz; their edges and crystal outlines are well preserved, and only rarely are they altered or muddied by inclusions. Judging from the analysis, these are probably soda orthoclases. Next to the feldspars, patches of chlorite occupy the most prominent place among the larger minerals. The chlorite is surrounded by a clear zone, which between nicols is seen to consist of feldspar laths. The arrangement of the groundmass points to the former presence of a mineral which has been replaced by the chlorite. From the shape of the chlorite areas, and because of the absence of any carbonates among the alteration products, which might have been expected if the original mineral had been hornblende or augite, this mineral is believed to have been biotite. A few pieces of an altered brownish-green mineral may be biotite, or possibly hornblende. A little secondary quartz, with indications of rhombohedral cleavage and clouded by inclusions, fills a few cavities and cracks in the rock.

The groundmass is composed of stringy, ragged feldspar microlites, often bent and curved. The feldspars are largely untwinned, although Carlsbads are found with the halves unevenly developed. Among the plagioclases sections were found with both Carlsbad and albite twinning, which made possible their determination as albite by Michel Lévy's method. When viewed with a low power the groundmass shows a general flow structure in the longitudinal direction of the flattened vesicles; but under higher powers the fluxional character is not very conspicuous, even around the larger feldspars. Yellowish cryptocrystalline aggregates found sparingly in the section may be devitrified glass. At present the whole slide is sprinkled with minute greenish-yellow dots, which may be considered as representing grains of some ferromagnesian mineral.

Analysis.—The alkalies present in the rock were determined by Dr. C. H. Warren, of the Sheffield Scientific School, and found to be: CaO, 1.06; Na_2O, 8.75; K_2O, .20. The trifling amount of potash was unexpected, and to guard against error a second determination was made, but with the same result. As the analysis shows, soda is the predominating alkili, and it must be the chief component of the feldspars. The rock itself falls into the group of soda trachytes or keratophyres.

Rocks of this group are rare in America, and for this reason they are interesting and worthy of considerable attention, even though their field occurrence has not been worked out in detail and complete analysis has not been made.

DOUBTFUL TRACHYTES.

Specimens of a trachytic-looking rock were collected on the South Branch of Caribou Stream in Woodland Township. The specimens have a fresh appearance and present two varieties. The greater part is a dense, bluish-gray rock, uniform in color and texture, and easily broken into any desired shape, while the other variety differs only in the presence of vesicular cavities ½ to 2 millimeters in diameter, which constitute nearly one-third of the whole mass. These two rock types are different parts of one lava flow of uncertain size. The cleavage cracks and cavities are now filled with calcite.

The microscope reveals an advanced state of alteration not suggested by the hand specimen, and the minerals can not be determined with certainty. The vesicles are found to be present in the dense variety also, differing from the others only in size. They are generally round, with a border of fine, fibrous calcite and chlorite alterations, and filled with chlorite or calcite. The groundmass, so far as can be read through the extensive alteration to carbonates, is of bent or curved orthoclase laths, which are long and narrow, with irregular outline, frayed-out edges, and ragged ends. The ferromagnesian minerals have entirely disappeared. The groundmass is trachytic in structure, with poorly developed flow structure. All that can safely be said of these rocks is that they are parts of a vesicular lava flow, probably belonging to the trachyte group.

QUOGGY JOE QUARTZ-TRACHYTE.

Macroscopic description.—The entire mass of the Quoggy Joe group of hills is of this material, and the drift bowlders and widespread talus make it a very common field rock over a large area. It presents various aspects, owing to its state of alteration, but is easily distinguishable from other rocks of the region by its white color when broken and by its method of weathering. The freshest material was found on the summit of the hill, where it has a whitish-gray or yellowish-chocolate color and is very dense and felsitic in appearance. The whole mass is cut by cleavage planes, and under the hammer a hand specimen breaks into rudely rectangular blocks, indicating numerous inconspicuous cleavages or planes of weakness. The fracture is uneven, and exposes a rough, trachytic surface with a certain silky sheen. The whole rock, weathered and fresh, is spotted with minute black and brown dots, which prove to be iron ore and alteration products.

Besides the planes of fracture spoken of, the rock shows many little long and exceedingly narrow cavities arranged in parallel rows, which seem to indicate stress insufficient to form complete cracks, but which may represent original vesicles drawn out by flow or shearing. These

slits are prominently brought out by weathering, and occasionally they are lined or even filled with quartz grains.

Surface alteration takes the form of a thin brown coat, which forms a sudden and conspicuous change from the white rock beneath. In no case does this outer coating exceed one-eighth of an inch in thickness, and there is never a gradation from the weathered part to the unaltered inner material, but immediately inside the brown coating the rock is as light colored and apparently as fresh as at the very center of the specimen. The cross section of a white block which had been painted black would show no more marked and sudden contrast between the wood and the paint than is exhibited in the weathering of specimens from Quoggy Joe. This distinct method of weathering is everywhere an important characteristic of rocks of this type, and is very useful in field determination. Occasionally this coating is stained with a shining blue-black manganese-bearing material.

Microscopic description.—The microscope reveals a rock composed of iron ore, albite, orthoclase, and quartz, with siderite, kaolin, and chlorite as decomposition products. The quartz is the only mineral which rises above the fine groundmass, and occurs as groups of grains usually surrounded by the iron carbonate. The individual grains are very irregular in their outline, and, as noted in the rhyolites, the groups have no common orientation. That some of the quartz is secondary is indicated by the fact that it fills minute cleavage cracks which traverse the rock in all directions, and is most abundant in the little slitlike cavities connected by these cracks. The slits noticed in the hand specimen are found to be arranged along lines now filled with quartz grains, and are understood to be local enlargements of imperfect cleavage and to have been formed by a stretching due to unequal movement and pressure.

The groundmass is composed of small, narrow feldspar microlites, arranged with typical trachytic structure, together with a great deal of quartz in finely divided particles. The feldspars are not easily determined, but they show many Carlsbad twins and albite twins, and these facts, taken in connection with their average extinction angle of 17°, indicate orthoclase and albite or andesine, but the small amount of lime, as shown by the analysis, would prevent the formation of andesine, and leaves albite as the probable plagioclase. The carbonate occurs in patches throughout the section, but is particularly abundant surrounding the partly quartz-filled cavities. Magnetite is found in specks and small dust aggregates, and the chlorite occurs in such forms and positions as to give no clue to the former mineral which it now represents.

Analysis.—The following analysis (I) of the freshest material obtained was made by Dr. W. F. Hillebrand, of the United States Geological Survey:

Analyses of quartz-trachytes and bostonites.

Constituent.	I.	II.	III.	IV.	V.	VI.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	72.77	70.23	69.00	62.30	62.28	72.88
Al_2O_3	12.15	15.00	13.95	17.05	19.17	12.90
Fe_2O_3	.44	1.99	1.56	1.30	3.39	.74
FeO	3.06	Undet.	2.38	2.46		1.05
MgO	.22	.38	.14	.57	Trace.	.75
CaO	.07	.33	.49	1.20	1.44	.81
Na_2O	3.38	4.98	5.67	5.14	5.37	3.72
K_2O	4.67	4.99	5.11	6.18	5.93	5.03
$H_2O-105°$	.17	.91	.70	.45	2.33	1.22
$H_2O+105°$	.55	1.28				
TiO_2	.20	?.03	.35	Trace.		.45
ZrO_2	.04			Trace.		
Cr_2O_3	None.					
V_2O_3	?					
NiO	None.					
MnO	.16	.24	.55			.05
BaO	.03					
SrO	None.					
Li_2O	?					
P_2O_5	Trace.	.06		Trace.		
CO_2	2.06			2.65		
Cl	?					
Fl	?					
FeS_2	(.067 S) .12			.43		
Total	100.09	100.42	99.95	99.73	99.91	99.60

I. Quartz-trachyte, Quoggy Joe Mountain, Maine. Analysis by W. F. Hillebrand, United States Geological Survey.

II. Bostonite (trachyte, keratophyre), Marblehead Neck, Massachusetts. Analysis by T. M. Chatard. Sears, Bull. Museum Comp. Zool. Harvard Coll., Vol. XVI, No. 9, 1890, p. 170.

III. Quartz-bostonite (quartzlindöite) Hof. Fron. Tartberg, Christiania, Norway. Analysis by U. Schmelck. Brögger, Eruptivegesteine des Kristianiagebietes, Grorudit-Tinguaite-Serie, p. 139.

IV. Quartz-bostonite (lindöit). Gjefsen Kirchspiel Gran. Norway. Analysis by L. Schmelck. Brögger, Eruptivegesteine des Kristianiagebictes, Grorudit-Tinguaite-Serie, p. 139.

V. Bostonite, Lake Champlain. Analysis by Kemp. Bull. U. S. Geol. Survey No. 107, 1893, p. 20.

VI. Aplite-granite dike, Castle Mountain, Montana. Analysis by Pirsson. Weed and Pirsson, Bull. U. S. Geol. Survey No. 139, 1896, p. 96.

Discussion of analysis.—This analysis shows some facts worthy of fuller mention. The carbonate present in such large quantity must

be almost entirely ferrous carbonate, as is common in rocks of this type.[1] It will be noticed that if a series of rocks of this type is to be constructed from comparison of the analyses, the Maine rock is the most acid type so far described, although some silica should be deducted for the secondary quartz present. The chemical composition of the quartz-trachyte differs little from that of the rhyolites (see p. 155), but the appearance of the two hand specimens is distinctly different. The aplite-granites (VI) have also much the same composition, but their structures, both macroscopically and microscopically, show characteristic differences.

The percentages of mineral components present in the Quoggy Joe quartz-trachyte have been calculated from the analysis and found to be as follows:

Mineral components of Quoggy Joe quartz-trachyte.

Mineral.	Per cent.	Mineral.	Per cent.
Quartz	34.97	Kaolin	1.66
Orthoclase	27.86	Chlorite	.50
Albite	30.46	Iron ore, etc	.44
Siderite	3.88	Total	99.77

Classification.—The term which should be applied to a rock of this character is not clearly evident. It belongs, however, to that variety of trachyte found in many places which is characterized by a white or creamy color, rough trachytic surface and appearance, a peculiar silky sheen, and a distinct mode of weathering. By this mode of weathering, which is rare for ordinary flow trachytes, but very characteristic for quartz-trachytes, the rock does not show gradations from weathered to fresh surface, but shows a thin dark outer zone which is suddenly replaced by the fresh white material within. Furthermore, so far as alterations can be considered characteristic, it is marked by the presence of siderite in place of calcite. Its microstructure is also characteristic in that it retains a typical trachytic structure of feldspar laths whose interspaces are filled with quartz, and not the granular structure common in alkaline rocks so full of silica. Hunter and Rosenbusch named rocks of this habit bostonite,[2] thus distinguishing a new class of dike rocks, and taking the Marblehead Neck outcrop as the type, although at that place it is apparently a surface flow. Chemically and mineralogically bostonites are practically trachytes, except that soda orthoclase is unusually abundant and the dark silicates are very few or are altogether lacking.

[1] Brögger, Das Ganggefolge des Laurdalits, p. 201.
[2] Tscher. Min. u. Petrog. Mitth. 1890, p. 447.

While the Maine rock has the characteristics of bostonites, it does not seem wise to enlarge the scope of the term, especially since its presence in petrographic nomenclature is of doubtful utility. The term quartz-trachyte is therefore used to denote the trachytic character of the rock under discussion and at the same time to indicate the high percentage of silica.

QUARTZ-TRACHYTE OF TOWNSHIP 9, RANGE 3.

The rock at this place is easily separated into blocks along the lines of fracture, which intersect one another at small angles. Examination of one of these small blocks shows a very dense yellowish-white material with a somewhat glistening surface. Within this felsitic groundmass are many specks of quartz about the size of a pin head, and a few larger cavities which are filled with quartz and carbonates, forming creamy-white areas with sparkling grains. Quartz also fills the minute cracks that are visible, and so secure is the cement that the rock is more easily broken in other directions than along these reunited fractures. In weathering, a rusty-gray zone about one-half inch thick is formed in which the cavities are filled with a yellow powder.

The minerals in a fresh specimen, as revealed by the microscope, are apatite, plagioclase, orthoclase, and quartz, together with muscovite, siderite, limonite, and a little calcite. The quartz forms perhaps one-third of the section and occurs as cement, closing fractures and filling in the spaces in the groundmass. The grains are usually broken into rude rhombs, and contain, as inclusions, numerous long, slender needles of apatite, together with occasional liquid inclusions. The feldspars form slender laths and a few square sections and are confined to the groundmass. The striated pieces about equal the unstriated in number, and since sections cut parallel to *b* can not show albite twinning, there is probably an excess of plagioclase over orthoclase in the section. By averaging many extinction angles the plagioclase was determined as oligoclase albite. Microperthite intergrowths occur. Muscovite forms part of the alteration products, and shows the cleavage and surface structure characteristic of micas, and also shows a very faint difference of absorption. The siderite and calcite are found in patches throughout the rock, while limonite forms the yellowish specks so prominent in the more weathered portions.

The structure of the groundmass is trachytic, although somewhat more granular than the Quoggy Joe specimen; quartz also takes a more important place among the feldspar laths.

ANDESITES.

Generally speaking, the andesites of this region belong to well-recognized varieties widely distributed over the earth, and differ in no

important particular from the type rocks of their class. Varieties are found here, however, which are intermediate between andesites and trachytes, and some with dacite facies are also found. The exposures are numerous and easy of access, and the specimens are no more altered in composition than if they were lavas of Tertiary age instead of Paleozoic.

AUGITE-ANDESITE.

Macroscopic description.—The largest and best single exposure of andesite in this region is of the augite-andesite variety, and forms the main mass of Edmunds Hill. It does not occur as a solid, compact mass at any part of the hill, but is broken by cleavage and shearing planes into large blocks on top, and into plates and slated material at the ends of the hill. This slated and seemingly bedded appearance, which is so unusual in an igneous rock, is the most marked peculiarity of the structure of the hill. In a few places the rock is seen to contain embedded angular pebbles of glass and baked siliceous material, which stand out when it weathers; and in other places the rock presents a banded surface of gray and brown, which gives the appearance of bedding, but which proves on examination to represent varying stages of decomposition along potential cleavages. With these exceptions the exposed rock has a uniform appearance, gray where weathered, black where fresh.

Andesites are such well-known rocks that an extended macroscopic description is unnecessary. The hand specimen appears as a black, basaltic-looking rock, generally dense, with a stringy effect and sprinkled over with glassy feldspars 2 millimeters and less in length. The weathered surface is a layer of spongy, gray-brown material, in which the pores are made by the decay of the larger feldspars. At the east end of the hill the rock is much lighter in color, and numerous white feldspars give it a more porphyritic appearance.

Microscopic description.—Microscopic examination reveals the composition and structure expected of a typical andesite. Magnetite, apatite, pyroxene, plagioclase, and orthoclase are the original minerals present. The plagioclase crystals range in size from laths 2 millimeters in length down to the very fine ones in the groundmass, but the larger ones are not abundant and do not give the rock a porphyritic aspect. The plagioclase forming the crystals outside the groundmass was determined by Michel Lévy's method to be labradorite; but the measurements indicated two labradorites, with the formulæ Ab_3An_4 and Ab_5An_6. The larger feldspars show strongly marked zonal banding, with occasionally as many as eight distinct zones, which decrease in basicity from the center outward, but with the original albite twinning running through the whole series. This albite twinning shows in nearly every feldspar lath with great distinctness, and twins on the

pericline and Manebach laws also occur. The Carlsbad twins present are often with one half dropped much below the other, and all the twinning is more or less along irregular ragged lines and with unsymmetric development. None of the feldspars are entirely fresh, but are kaolinized along the cleavages and zonal boundaries, or are entirely altered to kaolin and calcite except upon their outer borders. They also show irregular cracks other than cleavage, along which strain has been relieved. Glass inclusions, arranged without order, are numerous and stand out prominently in the clearer parts of the feldspars. Orthoclase was not found outside the groundmass, except as forming the wide outer rim of the zonally built plagioclases.

The pyroxenes are of both monoclinic and orthorhombic varieties. The monoclinic is an augite, light colored in thin section, with an average extinction on prism sections of 42°. The basal sections are quite fresh, and show the cleavage parallel to the prism. The pinacoids are more developed than the prism faces, and give the appearance of a square with truncated corners, rather than the more common octagonal effect. The prism sections vary from stout forms to those five or six times as long as broad. In places many small pieces are arranged in parallel position and separated by alteration products in such a way as to suggest the presence of augite phenocrysts, of which these fragments are the remnants. The orthorhombic pyroxenes are represented in the darkest-colored rocks by a few basal and prism sections, but in the gray varieties it constitutes fully half of the pyroxenes present. It is very light colored, not at all pleochroic, is at times partly eaten away, and in other cases occurs as intergrowths parallel with the augite. It seems to be a variety poor in iron; is optically +, and hence referred to enstatite. In the fresher rock specimens the cleavage cracks and borders of the enstatite often show the presence of a red-brown fibrous mineral. In the more weathered rocks this mineral assumes a prominent rôle. It is here found intergrown with augite and forming fibrous laths, with parallel extinction. Its pleochroism is distinct, with $\mathfrak{a}$=light brown, $\mathfrak{c}$=light green. The presence of this mineral in a slide seems to be in proportion to the absence of the orthorhombic pyroxene, and this, together with its shape and optical properties, points to bastite and makes plausible the supposition that the red-brown mineral is the present representative of the original orthorhombic pyroxene. The magnetite is present in grains or dust aggregates, and the apatite occurs in needles, laths, and rounded sections within the feldspars.

The groundmass consists essentially of long, narrow feldspar laths, with ragged outline and split ends, arranged with trachytic structure tending toward the hyalopilitic, and with flow phenomena developed in places. No close distinction can be drawn between the groundmass feldspars and those which rise slightly above it, as all sizes, up to the

very largest present, are represented. Optical measurements on some of the freshest pieces in the groundmass proved them also to be labradorite, although orthoclase must also be present, as demanded by the analysis. Besides the feldspars, augite grains are scattered abundantly throughout the mass, and small areas of brown glass, occasionally with bubbles, are also seen. The whole slide is darkened by iron dust, both magnetite and limonite or göthite. The rock is, however, in a remarkably fresh state, considering its age and position. Its character is unmistakable.

Analysis.—The analysis of this rock, made by Dr. W. F. Hillebrand, of the United States Geological Survey, is given below (I), and analyses of well-known andesites from other localties (II–VII) are given for comparison:

Analyses of andesites.

Constituent.	I.	II.	III.	IV.	V.	VI.	VII.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	61.40	61.58	61.29	61.04	61.45	61.17	63.25
Al_2O_3	16.59	16.96	17.68	15.72	15.07	17.74	14.89
Fe_2O_3	2.13	1.75	6.03	5.03	4.46	1.78	6.54
FeO	3.05	2.85	.30	2.15	1.18	3.51	None.
MgO	2.73	3.67	2.45	3.61	3.02	2.76	.82
CaO	6.17	6.28	5.61	5.34	5.37	5.90	.59
Na_2O	3.83	3.94	4.28	4.02	4.00	3.79	4.47
K_2O	1.34	1.28	1.38	2.66	1.22	1.71	4.78
$H_2O—105°$	.82	.24	.96	.58	1.23	.83	2.67
$H_2O+105°$	.88	1.06					
TiO_2	.79	.49	.65			.45	Trace.
ZrO_2	None.						
Cr_2O_3	Trace.					None.	
V_2O_3	.02						
NiO	Trace.						
MnO	.13	Trace.			None.	.12	
BaO	.02	.03				.06	
SrO	Trace.?	Trace.				.04	
Li_2O	Trace.	Trace.			.05	Trace.	
P_2O_5	.20	.22			Trace.	.14	.61
CO_2	None.						.78
Cl	?						
Fl	?						
FeS_2	None.				(SO_3.29)		Loss .53
Total	100.10	99.23	100.63	100.15	100.14	100.00	99.93

I. Andesite, Edmunds Hill, Aroostook County, Maine. Analysis by W. F. Hillebrand.
II. Hornblende-andesite, Mount Shasta, California. Analysis by H. N. Stokes, Bull. U. S. Geol. Survey No. 148, 1897, p. 190.
III. Hornblende-dacite, Anzeion, Ægina. Analysis by Dr. A. Röhrig. H. S. Washington, Jour. Geol., Vol. III, p. 150.
IV. Pyroxene-andesite, Peñon de Pitayo, United States of Colombia. Kuch, Geol. Studien in der Republik Colombia, Pt. I, Berlin, 1892.
V. Pyroxene-andesite, Agate Creek, Yellowstone National Park. Analysis by Whitfield, Bull. U. S. Geol. Survey No. 148, 1897, p. 134.
VI. Hypersthene-andesite, Crater Peak (Lassen Peak region). Analysis by W. F. Hillebrand, Bull. U. S. Geol. Survey No. 148, 1897, p. 197.
VII. ? Andesite, Fox Islands, Maine. Analyses by E. W. Magruder and W. A. Jones, in Johns Hopkins University Laboratory. G. O. Smith, Geology of Fox Islands, Maine. Presented as a thesis, Johns Hopkins University, 1896.

From a study of the above tables it becomes apparent that the Edmunds Hill rock presents no points of distinction from recognized types found elsewhere, and the tables could be greatly enlarged by the addition of closely similar analyses. The analysis in Column VII requires some notice. The rock is described as a red andesite, with "rather basic" feldspars and with calcite and magnetite present. The altered condition of the rock made accurate optical determination impossible. In discussing the analysis the writer says:[1] "In its mineralogical composition this rock approaches the basaltic type, but, as the analysis shows, is somewhat too acid. The olivine phenocrysts, moreover, are not very numerous, and there is reason to regard this as simply an olivine-bearing phase of the andesite." The description is of an andesite, but there are discrepancies between the description and the analysis. No ferrous iron is present to form magnetite, and if the small amount of lime forms calcite basic feldspars could not be produced, and even if the whole 0.59 per cent of lime were present as andesine or labradorite the amount is far too small for an andesite. According to the generally accepted usage among petrographers, a rock with so high a percentage of soda and potash, with little lime and magnesia, would be classed as a trachyte, or, more closely, an ægirine-trachyte.

HORNBLENDE-ANDESITE.

The largest single mass of this rock is Hobart Hill, and the freshest and most typical specimens are from this hill and from the west bank of the Presque Isle near the northeast foot of the hill, where quarrying was at one time attempted. The hand specimen shows a very dark-gray, almost black, rock, fine-grained, but with a somewhat porphyritic appearance, caused by the occasional feldspar crystals which rise above the general groundmass and reflect light well from their glassy cleavage faces. Some few feldspar laths attain a length of 5 to 6 millimeters. The rock breaks out into tabular blocks along the cleavages and weathers to a brownish-gray color.

Microscopic description.—In thin section the microscope reveals magnetite, apatite, titanite, occasionally a zircon lath, possibly augite,

[1] Geology of Fox Islands, Maine, p. 34.

hornblende, plagioclase, and orthoclase, together with considerable secondary calcite. The feldspars range from 2 millimeters in length down to minute microlites. The larger feldspars are commonly converted to calcite, which indicates their basic character, but also prevents their accurate determination. Those which could be measured by the Michel Lévy method proved to be andesine, with formula $Ab_1 An_1$, hence more acid than the feldspars of the augite-andesite. They contain glass inclusions, are zonally built with an occasional unaltered outer border, and are twinned according to the Carlsbad and albite laws, but with very irregular intergrowths of the parts.

Hornblende is the only important ferromagnesian mineral present, and occurs, as the feldspars, both as large basal sections and long laths, often with good crystal outline, and also as shreds in the groundmass. The larger pieces are rarely in a good state of preservation, but occur with ragged edges and show resorption phenomena. The crystal is eaten into, and part of the interior converted into magnetite with a few augite grains. Some crystals have been almost entirely replaced by calcite and magnetite, and others are represented by a ghostlike outline of magnetite dust. Commonly the hornblende is now changed to a green micaceous material, perhaps a variety of chlorite, with parallel extinction and a pleochroism, $\mathfrak{c}$=white green, $\mathfrak{a}$=brown green. At times the former crystal is striped in the direction of the cleavage cracks, with alternating bands of green and white. Some of the crystals classed as hornblende are so altered that it is impossible to say that they may not be augite.

The groundmass is formed of small, stringy, ragged feldspars, and varies in different slides from a trachytic or pilotaxitic type, with possibly a little glass, to a type formerly quite glassy and showing devitrified areas with incipient micropoikilitic structure. The feldspar microlites could not be accurately determined, but their average extinction indicates a variety as acid as oligoclase andesine, and if strict nomenclature were to be considered the rock would be classed as a trachyte-andesite.

SOUTHERN MAPLETON ANDESITES.

These occur in several localities, and are either identical with or present only minor variations from the Edmunds Hill and Hobart Hill masses. The rock which outcrops in the road 2 miles east of Mapleton Village has the most glassy groundmass of all the andesites, and its devitrified areas have the micropoikilitic structure the best developed. Two outcrops show a type much lighter in color, with much secondary and some original quartz, giving the rock a dacitic facies. The other sections examined are of the typical augite-andesite or hornblende-andesite of this region, and require no detailed description.

CASTLE HILL ANDESITES.

Macroscopic description.—The rocks at this place do not have the character of lavas which have formed thick flows, but rather suggest the surface of a flow. They are commonly amygdaloidal, or even slightly brecciated and ashy, and associated with them is an abundance of true volcanic ash with lapilli. The rock exposed at the southeast base of the hill is striking in its field appearance. Black, rusty-looking spheroidal or elliptical masses of lava, 1 to 2 feet in diameter, first attract attention as they lie loosely strewn over the surface. The solid ledge itself is composed of these forms, which have their outlines well displayed by weathering. These sacklike or pillow-shaped masses are plainly amygdaloidal on the surface, but usually much denser in the interior, and are cemented together by a coarse breccia of rough tabular, spheroidal, or irregular jagged fragments of glassy material and igneous rock of composition similar to the spheres. In some places, noticeably on McDonalds Hill, to the south of Castle Hill proper, this structure assumes the form of a conglomerate of small amygdaloidal spheres 6 inches and less in diameter, closely cemented together with angular pebbles of andesite and other igneous rocks. Similar structures have been described from California,[1] Scotland,[2] and elsewhere. As noticed by Geikie, some basic lavas, e. g., the basalt at Acicastello in Sicily,[3] assume a remarkable spheroidal or pillow-shaped structure on flowing into water or a watery silt, "the spheroids being sometimes pressed into shapes like piles of sacks." This may be the explanation in the present case. Another interpretation is that the structure represents the ropy, rolling surface at the front of a lava flow. On a fresh surface the rock is dark bluish gray, uniform in texture, or with a rare feldspar phenocryst. While this appears to be the most typical of the textures, it is usual to find vesicles now filled with calcite and fragments of volcanic débris large enough to constitute a conspicuous feature in the hand specimen. In weathering, the amygdaloidal parts go first and leave the more dense igneous and glassy pebbles exposed as a very rough surface. Pl. VII will give an idea of the external appearance of the rougher forms.

Microscopic description.—Sections were cut from the densest material, and also from that with macroscopic inclusions, and when examined with the microscope showed no difference except in size of vesicular areas and in method of alteration. Feldspar microlites make up the rock, parts of which are developed as areas of vesicular lava. The vesicles range from 2 millimeters in diameter to microscopic dots, and are rudely oval in outline. The large ones are merely the larger part of a rounded area of vesicular glassy lava, which con-

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[1] Ransome, Bull. Dept. Geol. Univ. California, Vol I, p. 106. Fairbanks, Bull. Dept. Geol. Univ. California, Vol. II, p. 40.

[2] Geikie, Ancient Volcanoes of Great Britain, Vol. I, p. 193.

[3] Johnston-Lavis, South Italian Volcanoes, p. 41.

tains a few feldspar threads, like the body of the rock. Sometimes, instead of one calcite-filled vesicle, the same space will be occupied by a group of them, or the concave inner border of the large one may indicate its formation from several smaller ones. There are some glassy oval areas with vesicles visible only under the highest powers. All these variations are, doubtless, caused by the fact that different sections of similar vesicular areas are exposed in the preparation of the slide. The only feldspar phenocryst seen in the sections is rounded in outline, has albite and pericline twinning, and is badly altered to calcite. Its extinction angle indicates albite or andesine, and, from the fact that phenocrysts are usually more basic than the components of the groundmass, it is referred to andesine. No ferromagnesian mineral is present, but the numerous patches of chlorite and the occurrence of augite in similar rock in the immediate neighborhood point to the former presence of pyroxene. Besides chlorite, there are present, as secondary products, calcite, a few epidote grains, and abundant iron ore. One slide is sprinkled full of stringy black iron ore in long threads or lines of partly connected dots, which are arranged to form barbed arrows or a network of fibers that cross at angles of 60° and 90°, thus imitating the sagenite structure of rutile.

The groundmass is of long, stringy, narrow, frayed-out microlites of feldspar with trachytic structure. Measurements of many laths gave practically a parallel extinction, thus indicating oligoclase. Expansion structure is developed where the vesicular areas are large enough to affect the orientation of the minute laths constituting the main body of the rock.

ANDESITE ASH BEDS.

Beds of volcanic ash of an andesite character are represented in the region covered by this report. They are particularly abundant about Castle Hill, and are discussed in the chapter on clastic rocks.

DIABASE.

AROOSTOOK FALLS DIABASE.

The diabase from Aroostook Falls is a dark-gray rock with characteristic lamprophyric appearance, quite dense and uniform in texture to the unaided eye, with the exception of numerous grains of pyrite and a few greasy-looking feldspars which give it a slight porphyritic facies. It weathers to an iron-rust color, but the face of the dike next the limestones often shows a jet-black slickensided surface, as if some carbonaceous matter had been produced by the intrusion.

Under the microscope the minerals found in this section are apatite, iron ore (mostly pyrite, which is abundant), pyroxene, and plagioclase, with chlorite as an alteration product. The larger feldspars (1 millimeter in length) form crystals whose basic character is suggested by their alteration to calcite, but which are too much decomposed to

measure. No other mineral rises above the groundmass, and the whole section otherwise shows a uniform aggregate of feldspar laths, which are stout rectangular to long irregular in shape, and among them are embedded more or less rounded grains of quite fresh, colorless pyroxene. The structure of the groundmass is therefore not the ordinary ophitic type common to diabases, but corresponds to the granulitic type of Judd.[1] The feldspar microlites show twinning, but could not be satisfactorily measured, and their basic character is calculated from the analysis. A quantity of the rock powder was tested for nepheline, but it yielded no gelatinous silica.

Analysis.—The following analysis (I) of a specimen from the largest dike was made by Dr. W. F. Hillebrand, of the United States Geological Survey.

Analyses of diabase.

Constituent.	I.	II.	III.	IV.	V.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	49.64	49.27	52.37	51.80	49.25
Al_2O_3	15.07	15.87	15.06	14.21	16.97
Fe_2O_3	1.66	1.93	2.34	3.55	15.21 (with FeO)
FeO	8.82	10.17	9.82	8.26	
MgO	5.43	5.90	5.38	7.63	3.00
CaO	7.23	7.46	7.33	10.68	7.17
Na_2O	4.19	3.45	4.04	2.15	4.91
K_2O	.89	.74	.92	.39	2.01
H_2O-105	.45	3.92 (both)	2.24	.63	.30
H_2O+105	2.81				
TiO_2	2.32		.21		1.41
ZrO_2	None.				
Cr_2O_3	Trace.				
V_2O_3	.04				
NiO	Trace.				
MnO	.25	.35	.32	.42	Trace.
BaO	.02				
SrO	.05				
Li_2O	Trace.				
P_2O_5	.29			.14	.76
CO_2	.32	1.12			Trace.
Cl	?				
Fl	?				
FeS_2	(.43 S) .79				
Total	100.27	100.18	100.03	99.86	100.99

[1] Judd, Gabbros, etc., in Scotland and Ireland; Quart. Jour. Geol. Soc., Vol. XLII, 1886.

I. Diabase from Aroostook Falls, New Brunswick. Analysis by W. F. Hillebrand, United States Geological Survey.
II. Diabase or chloritic dolerite from Lake Saltonstall, Connecticut. Analysis by G. W. Hawes, Trap rocks of the Connecticut Valley: Am. Jour. Sci., 3d series, Vol. IX, 1875, p. 190.
III. Diabase from Reeds Gap quarry, Middlefield, Connecticut. Analysis by Dr. J. H. Pratt, of Sheffield Scientific School. (Not published.)
IV. Diabase (dolerite) from West Rock, New Haven, Connecticut. Analysis by G. W. Hawes, Trap rocks of the Connecticut Valley: Am. Jour. Sci., 3d series, Vol. IX, 1875, p. 186.
V. Essexite (olivinegabbro-diabase). Dignæs. Kirchspiel Gran. Norway. Analysis by Schmelck. Brogger, Quart Jour. Geol. Soc. London, Vol. L, 1894, p. 19.

Discussion of analysis.—The above analyses show that in composition the Maine rock is very near those diabases of the Lower Connecticut Valley which have been mapped as extrusives, while it is somewhat lower in lime and higher in soda than the specimen from West Rock (IV), which is typical for the intrusive sheets of the region. Analysis V is given to show the relation to the essexites and rocks of similar character. Comparison with many analyses other than those given in the table suggests the idea that the Aroostook Falls dike is a transition between a diabase of normal type and rocks of the theralite-essexite magma.

MARS HILL DIABASE.

The two dikes found at this locality differ widely in appearance and type of structure. The easternmost dike closely resembles the rock described from Aroostook Falls and is considered as normal for this region. The other dike is exceedingly basic in composition and is microscopically characterized by the presence of a glassy base.

NORMAL TYPE.

The normal type of diabasic dikes forms the easternmost occurrence at Mars Hill. Owing to the presence of pyrite and a few feldspars larger than the microlites of the groundmass, the rock appears slightly porphyritic to the unaided eye, and on much weathered surfaces it presents a bleached, slaggy appearance. Securely cemented within the diabase are fragments of a blood-red jasper, which vary in size from mere specks to blocks several feet square. These jasper inclusions are never rounded, but present straight, clear-cut edges against the diabase and show clearly the marks of stratification. It is also noticeable that the center of the jasper blocks is a dull brownish-red, amorphous-looking, baked slate, while at the contact with the igneous rock it becomes blood red and has a shiny crystalline appearance. These jasperlike fragments are considered siliceous iron-bearing slates, which have been broken off and included by the dike in its ascent, and which in consequence have been metamorphosed.

Microscopic description.—Under the microscope feldspar and augite appear as the components. The few small phenocrystic feldspars are too badly decomposed to be determined, but if more basic than those constituting the groundmass, as is to be supposed, they are probably

andesine. The feldspars of the groundmass are long, narrow, poor bounded individuals, nearly all striated, with an extinction nearly pa allel, and hence oligoclase. Colorless augite is scattered thick through the slide, commonly as grains, but also as prisms and bas sections, and these occasionally extinguish in common, thus suggesti the ophitic structure. In places the feldspar microlites have son tendency to a spherulitic structure. Chlorite and iron are abunda in specks and patches, and calcite and quartz, together or separatel occupy the cracks in the rock.

The included jaspers are too dense to show structure and are oft partly surrounded by material composed of fragments of arkos feldspar, and quartz grains, set in a fine groundmass of similar materia This would indicate that the jasper was already part of a conglom erate when fragments were removed by the igneous intrusion. It possible, however, that the presence of the arkose is due to seconda processes.

GLASSY TYPE.

The glassy type appears in the hand specimen as an exceedingl dense, blue-black rock with a dull luster and without the ordina characteristics of vitreous material. Occasionally a small dot of r jasper is visible, but no other structures or minerals can be seen. T rock is very tough, and where struck with a hammer is reduced to powder of a lavender-gray color. Slickensides along the intersecti cleavages show movement since the mass has been in place.

A thin section examined under the microscope revealed no minera present except a few rounded augite grains and some serpentine fillin cracks, but it showed a groundmass composed entirely of very minut feathery fragments of some material which was not resolvable under t highest powers. These feathery structures are so arranged abo centers as to form round or elliptical spherulitic aggregates. Dire evidence as to the nature of this groundmass is wanting, but that it glassy and formed by sudden cooling seems evident. Whether t spherulitic structure is secondary or primary, or, if secondary, wh its former nature was, is doubtful. The suggestion is made that may have been formerly a perlite reduced to its present condition b devitrification. A few glassy spheres remaining in one place bear o this supposition. The whole slide is densely sprinkled with chlori and iron dust, thus bearing testimony to the basic character which t analysis brings out so clearly.

Analysis.—The following analysis (I) by Dr. W. F. Hillebrand, of th United States Geological Survey, was made from the freshest materi obtained. Analysis II is inserted for comparison.

Analyses of basic diabase.

Constituent	I.	II.	Constituent	I.	II.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
SiO_2	42.25	42.5	V_2O_3	.07	....
Al_2O_3	16.87	12.7	NiO	.01	....
Fe_2O_3	5.24	....	MnO	.40	1.30
FeO	19.72	11.40	BaO	Trace?	....
MgO	6.91	6.80	SrO	None.	....
CaO	3.33	13.10	Li_2O	Trace.	....
Na_2O	3.96	5.08	P_2O_5	.34	1.30
K_2O	.77		CO_2	None.	....
$H_2O-105°$	.43	6.50	Cl	?	....
$H_2O+105°$	5.58		Fl	?	....
TiO_2	2.93	....	FeS_2	(Trace S.)	....
ZrO_2	None.	....		Trace.	....
Cr_2O_3	.03	....	Total	99.84	100.68

I. Glassy diabase, Mars Hill, Maine. Analysis by Dr. W. F. Hillebrand, United States Geological Survey.

II. Limburgite (magma basalt), Hohe von Skalka, Bohemia. Analysis by Boricky. Math.-naturwiss. Class zu Prag, Jan. 12, 1872: cit. Jahrb. Min. 1872, p. 959.

Discussion of analysis.—The above analysis indicates a basaltic magma between the gabbro and the peridotite groups. In the absence of crystallized minerals only theoretical compositions can be calculated, but it is very probable that a magma so rich in magnesia and ferrous iron would form, on crystallization, much olivine, and, with the abundant alumina, augite also. These minerals would require all the lime present, and hence feldspars containing the anorthite molecule could not be formed, but rather nepheline, or, if water were present, analcite. In such a case the basic lamprophyric dike would be classed as nepheline-basalt or analcite-basalt.

TESCHENITES.

FIELD APPEARANCE.

The field appearance of this rock is characteristic, and a person with but slight acquaintance with igneous rocks would not confuse it with the other dikes or with the lavas of this region. But in spite of its general characteristic appearance, its variation within certain limits is remarkable, as has been noticed in rocks of this class from other localities. So great is this variation that at first sight the impression is conveyed that there are here a number of dikes of somewhat different composition and structure which have interpenetrated one another or come up as parallel intrusions. They are all parts of one dike, how-

ever, and no line of demarcation is possible between the different phases. The teschenites are readily decomposed by weathering, breaking down in place to a fine, brown sand, which accounts for the absence of sharp cliff ledges at the outcrops and makes it difficult to secure unaltered material. Even the specimens obtained by blasting, which appeared beautifully fresh in the field, were found by examination of thin sections to contain many altered minerals.

In the following description the varieties obtained will, for the sake of simplicity, be grouped under three heads: the coarse crystalline type, the granular type, and the contact facies. For a map of this district see page 116.

COARSE CRYSTALLINE TYPE.

This constitutes nearly all the great dike on lot 100 and the outcrop at the northeast corner of lot 107.

Macroscopic description.—Typical hand specimens show a rock made of a mixture of white or pink and lustrous black materials in about equal quantities, but with a tendency toward aggregation of like parts which makes dark and light areas. The light parts are composed of white or pink feldspars, in the midst of which are good-sized areas of milk-white analcite. The dark parts are composed of black augite mingled with grains of magnetite. Masses of oily green chloritic material are also macroscopically apparent. The crystals will average 5 to 6 millimeters in largest diameter. From this type, in which the dark and light components appear equally represented, there is a variation on the one hand to a black crystalline aggregate of augite and iron, and on the other to a tangled mass of feldspar laths, filling the interspaces and containing black minerals without definite outlines. One feldspathic variety is unique in some particulars. It is composed largely of good-sized, perfectly formed pink feldspar, with shining cleavage faces and with the ferromagnesian minerals wanting or reduced to inconspicuous grains. The rock is much weathered and shows numerous irregular cavities, from which some mineral has been removed and which are now lined with black dust or rarely filled with calcite. Such cavities are found also in weathered parts of the other varieties.

Microscopic description.—Several slides of this coarse type of the teschenites were prepared, none of which showed all the minerals in good condition, but the character of each was very well made out by a comparative study. The minerals present in the order of their formation are: Black iron ore, with a few grains of pyrite; apatite, biotite, feldspar, augite, and analcite. This order, however, is not strictly observed, and the appearance is more as if several minerals had been crystallizing simultaneously. The iron ore is largely magnetite and is very abundant in the section as partly formed polygons or irregular

rains, with bays and internal cavities often filled with biotite or its lteration product. The aggregation of biotite and magnetite is oticeable in all the sections. The large amount of titanium given ı the analysis suggests ilmenite, but the iron grains are readily picked p by the magnet. Apatite is thickly distributed through the rock ı long broken needles and well-formed crystals which penetrate the eldspars in particular very deeply.

The biotite is a pale yellow-brown variety, pleochroic, with distinct leavage and .regular or ragged border, and is found included by or rouped with the magnetite, or more rarely scattered through the ection. It is found in various states of alteration, and stages can be raced from the yellow unaltered biotite to a deep-red, fibrous or comact serpentinous mineral. This alteration product appears somewhat ke the iddingsite found in the California teschenite[1] and quite comıonly in basalts, but there is here no olivine represented by crystal utline or characteristic parting, nor lines of alteration, as is the case ı slides where the red mineral occurs as the undoubted secondary ıineral after olivine, and therefore the presence of olivine is not ssumed.

Augite is the most prominent rock constituent by reason of its evelopment into large, well-formed crystals and its beautiful violetrown color and faint pleochroism. The prism sections, which are oout twice as long as broad, sometimes attain a length of half an inch ıd may have perfect crystal boundaries or broken, irregular edges. asal sections are generally almost square by slight development of rism faces, but show also rounded and rectangular outlines. In some oecimens the violet augite has a light-green border of some ægirine ype of pyroxene, which is also occasionally present apart from the ıgite. The augites have altered along the cleavages to the same eddish mineral found replacing the biotite, and occasionally the crystal entirely replaced by a green chloritic mineral or by calcite, or may e bordered by a zone of serpentine, often in radial bunches.

The feldspars occur typically in long, broad laths or narrow, rodke bodies. They are nearly all striated and occasionally have Carlsıd twinning. The largest crystals are in the pink variety, and here, ı in all types, alteration products prevent accurate determination in ıe majority of cases. However, sections are present in the slide hich have the albite and Carlsbad twins developed and are fresh and ight in appearance. One such section was cut in the zone suited for otical determination by the Michel Lévy method, and gave the folwing measurements: Albite extinction, 13°; Carlsbad, 4°; the differıce is 8°, and by reference to the table is found to correspond to the

[1] Bull. Geol. Dept. Univ. California, Vol. I and Vol. II.

composition Ab_5An_3, and is therefore andesine (see fig. 11). The most common alteration is a clouding by means of myriads of minute specks of pure white analcite, which is distributed without order along cracks or in the center, or as a zone surrounding the crystal. The feldspar also shows chlorite or serpentine along the cracks, or may be striped by alternate bands of chlorite and calcite.

A whitish isotropic mineral, with low refraction and birefringence abundantly present in the rock, suggested leucite, sodalite, and analcite. In order to determine which of these minerals was present, a portion of the rock powder was treated with dilute nitric acid and then filtered, and the filtrate yielded gelatinous silica so easily and abundantly that the mineral could not be leucite. A test of a portion of the original filtrate showed no chlorine, which the presence of sodalite would demand. Moreover, the rock yields water abundantly below red

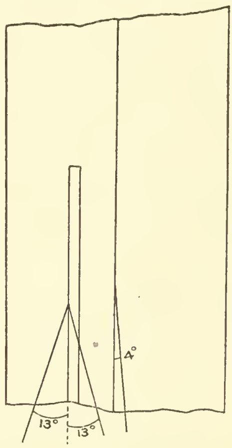

FIG. 11.—Optical measurements of a plagioclase crystal.

heat in the closed tube. Analcite is the only rock-making mineral which corresponds in composition and optical behavior to the one under discussion.

The analcite of the teschenite is either pure white or clouded by dust particles, and the slight birefringence is accordingly variable. It occurs abundantly in the typical slides, filling the polygonal areas between the interlacing feldspars, or filling cavities partly bounded by crystal faces, or as the secondary product described above. No alteration to secondary minerals, as has been recorded by Fairbanks, was observed. The disputed question of the origin of the analcite in rocks of this class finds no additional evidence here, but the writer believes, with Rosenbusch[1] and Fairbanks,[2] that it is secondary probably after nepheline, and not primary, nor secondary after feldspar, as maintained by Rohrback.[3]

[1] Rosenbusch, Mikrosk. Phys. der mass. Gesteine, p. 253.

[2] Fairbanks, Bull. Geol. Dept. Univ. California, Vol. I, p. 284; Vol. II, p. 27.

[3] Rohrbach, Ueber die Eruptivegesteine im Gebiete der Schlesich-Mährischen Kreideformation: Tschermaks Mittheilungen, 1886, Vol. VI, p. 31.

The structure is, in a way, the ophitic of the diabases, in that the feldspars have crystallized before the augites, but the arrangement is not one where augite grains with common orientation fill the interspaces between the feldspar laths, but single large augite crystals are cut into two or more separate parts by rodlike feldspars which penetrate them at different angles, and the effect between crossed nicols is somewhat suggestive of poikilitic structure. An average of all the coarsely crystalline specimens would give a structure between the granitoid and that of ordinary diabases. It is indeed quite probable that all of the essential components were in process of formation at one time.

Analysis.—The following analysis (I) by Dr. W. F. Hillebrand, of the United States Geological Survey, was made from the freshest specimen of the coarse crystalline variety from the dike cut through by the wagon road:

Analyses of teschenites and related rocks.

Constituent.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	46.77	44.65	44.31	47.67	48.18	49.61	46.48	46.99
Al_2O_3	14.91	13.87	17.20	18.22	11.80	19.18	16.16	17.94
Fe_2O_3	7.80	6.06	4.64	3.65	9.79	2.12	6.17	2.56
FeO	4.90	2.94	3.73	3.85	5.90	5.01	6.09	7.56
MgO	2.94	5.15	6.57	6.35	6.05	4.94	4.02	3.22
CaO	6.30	9.57	10.40	8.03	7.50	10.05	7.35	7.85
Na_2O	4.97	5.67	4.45	4.93	3.46	5.62	5.85	6.35
K_2O	2.37	4.49	3.64	3.82	1.57	1.04	3.08	2.62
$H_2O-105°$	.92	.96	.77	.38	3.20	3.55	4.27	.65
$H_2O+105°$	4.28	2.10	3.30	2.97				
TiO_2	2.31	.95	Undet.	Undet.			.99	2.92
ZrO_2	None.							
Cr_2O_3	None.							
V_2O_3	.02							
NiO	Trace.							
MnO	.29	.17	.10	.28				Trace.
BaO	.04	.76						None.
SrO	.03	.37						
Li_2O	Trace.	Trace.						
P_2O_5	.98	1.50			.49	.27		.94
CO_2	Trace?	.11			.71		.45	
Cl	?	Trace.			Trace.			
Fl	Trace.							
FeS_2	(.036 S) .07	(SO_3 .61)						
Total	99.90	99.92	99.11	100.15	98.65	101.39	100.91	99.60

I. Teschenite from Mapleton Township, Aroostook County, Maine. Analysis by Dr. W. F. Hillebrand, United States Geological Survey.

II. Theralite from Gordons Butte, Crazy Mountains, Montana. Analysis by E. A. Schneider, Bull. U. S. Geol. Survey No. 148, 1897, p. 146.

III. Theralite from Gordons Butte. Another sample of II. Analysis by Schneider.

IV. Theralite, north of Alabaugh Creek, Crazy Mountains, Montana. Analysis by E. A. Schneider, Bull. U. S. Geol. Survey No. 148, 1897, p. 146.

V. Teschenite from Boguschowitz, Silesia. Analysis by Tschermak, Tschermaks Min. und Petrog. Mitth., Vol. VI, 1885-86, p. 42.

VI. Augite-teschenite, Point Sal, California. Analysis by H. W. Fairbanks. Fairbanks, Geology of Point Sal: Bull. Dept. Geol. Univ. California, Vol. II, 1896, No. 1, p. 31.

VII. Monchiquite, Brazil. Analysis by Hunter, Tschermaks Min. und Petrog. Mitth., Vol. XI, 1890, p. 464.

VIII. Essexite from Salem Neck, Massachusetts. Analysis by H. S. Washington. Washington, Petrographical Province of Essex County: Jour. Geol., Vol. VII, 1899, No. 1, p. 57.

Discussion of analysis.—An inspection of the analysis (I) shows that there is not enough ferric oxide to convert the titanium dioxide and ferrous oxide into iron ore, and it is probable that part of the titanium dioxide is present in the augite, as would be expected from its violet color. It is evident that the soda and potash could not be converted into feldspar without forming a variety much richer in soda than the analysis shows. Perhaps soda orthoclase is present, but it seems quite certain that there is also some sodium aluminate compound besides feldspar in the rock. Furthermore, the amount of silica present is not sufficient to convert the potash, soda, and lime into feldspars, and some feldspathoid would be formed; this was most likely nepheline. Some of the analcite present is certainly secondary, and it is quite probable that it all is so.

Comparison of the analyses in the table given above will show the close relationship between the Maine rock and the typical theralites, and it is very probable that the former was a theralite in its original condition.

In regard to the essexite (VIII), Dr. Washington says that "nepheline is fairly abundant, generally interstitial, but occasionally in well-shaped crystals."[1] This fact, together with the closely similar chemical composition, goes to show how closely related are the members of the theralite-essexite-teschenite series.

GRANULAR TYPE.

Macroscopic description.—The same minerals are found in this tpye as in the coarsely crystalline, but their form, relative abundance, and method of arrangement are different. In the hand specimen no distinct crystals are seen and the rock appears more as a fine, even-grained, brown sandstone. The areas where this type occur are very different in appearance from the other parts of the large dike, but are not separated by any distinct boundaries. The specimen from lot 100 has the character of a fine-grained lamprophyre.

[1] Jour. Geol., 1899, Vol. VII, No. 1, p. 54.

Microscopic description.—The microscope shows the feldspars shorter and narrower than those in the main dike mass, the micas much more abundant, and the augite, now largely represented by chlorite, in grains or small granular crystal sections, and not in long prism sections. Their color and pleochroism, too, are absent. The apatite is in exceedingly fine needles, and calcite is more common as an alteration product. The iron is still abundant, but in smaller, irregular grains and crystals.

The granular representative from lot 106 is in the nature of a transition from the rock just mentioned to the crystalline type. The minerals revealed by the microscope are as before—iron, apatite, mica, feldspar, and analcite. Iron is in small, black and brown, irregular or polyhedral grains. Biotite is the most abundant dark mineral and occurs in good-sized sections, which often show alteration to the yellow-red mineral common in all these rocks. The augite is almost colorless and occurs as small crystal sections and grains, always of smaller size than the mica, and never becoming a markedly noticeable component. The feldspars are oligoclase in laths shorter and narrower than the other types, and the analcite is not a prominent constituent. In structure this granular variety resembles the groundmass in fine-grained panidiomorphic kersantite.

CONTACT FACIES.

Macroscopic description.—A few feet from the sedimentaries on the south the teschenite of the dike along the west side of lot 99 assumes a particular variation due to contact with the slates. The rock here assumes a deep-black color, is exceedingly dense and tough, and is distinctly porphyritic by the presence of pink feldspar laths and an occasional augite crystal in the cryptocrystalline groundmass. At the contact the hand specimen shows numerous angular fragments of slates embedded in the igneous rock and tongues of the teschenite, reaching into the hardened slates, but no smooth contact walls were observed. Weathered surfaces show cavities left by decaying feldspar phenocrysts, which give the rock a porous aspect.

Microscopic description.—Microscopic examination reveals a black cryptocrystalline groundmass in which are embedded phenocrysts of feldspar and augite. The augite is represented only by its outline, which, however, is perfect, and with its bright filling of calcite stands in marked contrast to the black groundmass. The feldspars also have clear crystal outlines, rarely with notched ends, and have nearly all gone over to calcite.

The groundmass is composed of a black dust with particles arranged in blotches or rude spherulitic form so as to leave yellow areas between them. Under the highest powers the radial structure is more pro-

nounced in the black areas. Between crossed nicols the black is isotropic, and the yellow spots are but faintly birefringent. A great quantity of iron dust seems to be present, and probably some glass also.

The slates included in the rock are hard, gray fragments composed of minute quartz and feldspar grains, together with secondary chlorite and calcite.

The specimen from Castle Hill is very badly decomposed, but the abundance of apatite, the presence of the violet augite, and the general structure of the rock all indicate similarity to the typical teschenite of Mapleton.

CHAPTER V.

GENERAL PETROLOGY.

The igneous rocks of the Aroostook area are widely separated in geographic position, and yet the distinctive volcanic types are found in a rather limited district.

The granite areas are small and about 40 miles apart. The diabase dikes are not numerous, and typically are found cutting the folded and slated Aroostook limestone. The lavas—rhyolite, trachyte, and andesite—are contained within an area about 12 miles by 6 miles, and with them are found the most typical tuffs and volcanic conglomerates. As the land exists to-day the Castle Hill–Mapleton area appears as a distinct center of volcanic activity within which intrusions and extrusions have formed at the same or different times. The presence of lavas of different character is not inconsistent with the idea of a limited center of activity, and all the field relations indicate a few small vents or fissures rather than powerful volcanoes which have ejected immense quantities of lava.

No petrologic work has been done previously anywhere near this region, but from the field descriptions of geologists limited areas of similar rocks are supposed to exist in northwest New Brunswick, in eastern Quebec, and along the lakes in central Maine. Specimens collected at Temiscouata Lake by Prof. H. S. Williams are andesitic tuffs and breccias. Along the coast line the rocks have been studied at St. John, New Brunswick, and found to be granite-diorites, gabbros, felsite, porphyries, diabases, and porphyrites.[1] Farther west along the Maine coast aporhyolites, andesites, and other volcanics have been described.[2] In the province of Quebec, on the west of Maine, large areas of anorthosite exist, some of which have been studied[3] by the Canadian survey. It is to be hoped that more of these isolated areas within the sedimentary slates will be described and some data secured which will permit a discussion of their general petrology in detail.

The analyses of all the rocks from this region are here given in one table, for ready reference.

[1] W. D. Matthew, Trans. New York Acad. Sci., Vol. XIII, 1894, p. 185, and Vol. XIV, pp. 187–217.
[2] Bayley, Bull. Geol. Soc. America, Vol. VI, 1894, p. 474,. Smith, Geology of the Fox Islands, Maine.
[3] See the writings of F. D. Adams.

Analyses of rocks from northeast Maine.

[Analyst, Dr. W. E. Hillebrand.]

Constituent.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
SiO_2	75.98	72.77	61.40	49.64	42.25	46.77	31.42	54.23
Al_2O_3	12.34	12.15	16.59	15.07	16.87	14.91	11.57	7.38
Fe_2O_3	.85	.44	2.13	1.66	5.24	7.80	2.37	.54
FeO	.93	3.06	3.05	8.82	10.72	4.90	7.48	1.37
MgO	.15	.22	2.73	5.43	6.91	2.94	5.32	3.29
CaO	.13	.07	6.17	7.23	3.33	6.30	16.71	14.65
Na_2O	4.02	3.38	3.83	4.19	3.96	4.97	2.26	1.65
K_2O	4.44	4.67	1.34	.89	.77	2.37	.74	1.74
$H_2O-105°$	.24	.17	.82	.45	.43	.92	.76	.25
$H_2O+105°$	.64	.55	.88	2.81	5.58	4.28	4.17	1.22
TiO_2	.17	.20	.79	2.32	2.93	2.31	2.30	.28
ZrO_2	.03	.04	None.	None.	None.	None.	None.	?
Cr_2O_3	?	None.	Trace.	Trace.	.03	None.	Trace.	?
V_2O_3	?	?	.02	.04	.07	.02	.06	?
NiO	None.	None.	Trace.	Trace.	.01	Trace.	Trace.	None.
MnO	Trace?	.16	.13	.25	.40	.29	.38	N. est.
BaO	.07	.03	.02	.02	Trace?	.04	.64	None.
SrO	Trace?	None.	Trace.	.05	None.	.03	None.	None.
Li_2O	Trace?	?	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
P_2O_5	.03	Trace.	.20	.29	.34	.98	.46	.07
CO_2	None.	2.06	None.	.32	None.	Trace?	13.13	13.48
Cl	?	?	?	?	?	?	?	?
Fl	?	?	?	?	?	Trace.	?	?
FeS_2	None.	(.067 S) .12	None.	(.43 S) .79	(Trace S) Trace.	(.036 S) .07	(.086 S) .16	?
Total	100.02	100.09	100.10	100.27	99.84	99.90	99.93	100.06

I. Rhyolite, Haystack Mountain.
II. Quartz-trachyte, Quoggy Joe Hill.
III. Andesite, Edmunds Hill.
IV. Diabase, Aroostook Falls.
V. Diabase, Mars Hill.
VI. Teschenite, near Mapleton Village.
VII. Volcanic tuff, southeast base of Castle Hill.
VIII. Calciferous sandstone, New Sweden Township.

These analyses show that the igneous rocks of the district are of an alkaline type. The andesite (III) is of the ordinary plagioclastic character, but the rocks more acid and those less acid than the andesites show an alkaline tendency. This is the most evident point in their regional affinity.

CONTRIBUTIONS TO THE GEOLOGY OF MAINE.

Part III.—LIST OF LOCALITIES OF PALEOZOIC, IGNEOUS, AND OTHER CRYSTALLINE ROCKS EXAMINED DURING THE SEASONS OF 1897 AND 1898

BY

H. S. WILLIAMS

CONTENTS OF PART III.

CONTRIBUTIONS TO THE GEOLOGY OF MAINE.

PART III. LIST OF LOCALITIES AT WHICH OUTCROPS WERE EXAMINED DURING THE SEASONS OF 1897 AND 1898.[1]

By Henry S. Williams.

AROOSTOOK COUNTY, MAINE.

[Arranged in order of townships.]

1295. Houlton (Township 6, Range 1).
   - A. An exposure on east side of railroad, south of station near the bridge.
   - B. Cut on Bangor and Aroostook Railroad, half a mile north of Houlton Station, at milepost 128 from Oldtown.
   - C. Cut on Canadian Pacific Railroad, three-fourths mile southeast of station at Houlton.
   - D. On Merrithew's farm, near Greenville Station, on Canadian Pacific Railroad. (This farm may be in New Brunswick.)
   - E. Falls on South Branch Meduxnekeag River, at Carys Mills.
   - F. Cut on Bangor and Aroostook Railroad, 1,200 feet north of milepost 128 from Oldtown, three-fourths mile north of Houlton Station.
   - G. Cut on Bangor and Aroostook Railroad, 1,500 feet north of milepost 128 from Oldtown, three-fourths mile north of Houlton Station.
   - H. Cut on Bangor and Aroostook Railroad, at milepost 129 from Oldtown, 1½ miles north of Houlton Station.
   - K. In field just west of Canadian Pacific Railroad station, Houlton.

1296. Mars Hill, Blaine (Township 10, Range 1).
   - A. About one-fourth mile southwest of station, at Mars Hill, in a field east of Joe Lincoln's house.
   - B. In village of Mars Hill, east side of river, at dam, corner of road.
   - C. Cut on Bangor and Aroostook Railroad, one-third mile north of station at Mars Hill.
   - D. In field, about one-fourth mile west of Joe Lincoln's house (1296 A).
   - E. East side of starch factory, 1 mile northeast of Mars Hill post-office.
   - F. In field, northwest corner of Mars Hill Mountain, east of road, by a bridge.
   - G. On George York's place, northeast corner of Mars Hill Mountain, hillside south side of brook, in woods.
   - H. East side of north end of Mars Hill, just above (on northeast side) brook on George York's place, in woods, three-fourths mile south of house.
   - J. Cut on Bangor and Aroostook Railroad, 750 feet north of milepost 156 from Oldtown, 1.86 miles south of station at Mars Hill.

[1] The localities are arranged by townships, and the numbers are station numbers of the United States Geological Survey catalogue and are attached for identification to the specimens, which will ultimately be deposited in the National Museum. References to these station numbers are made in both the paleontologic and the petrographic notes of this report, and in cases not actually recorded in this report are preserved in field and laboratory notebooks for future reference.

1296. MARS HILL, BLAINE (TOWNSHIP 10, RANGE 1)—Continued.

K. South end of Mars Hill, west side, section running from bottom (McPherson's house) to highest summit.

L. Cut on Bangor and Aroostook Railroad, Robinson Station.

M. Cut on Bangor and Aroostook Railroad, one-fourth mile north of milepost 155, one-third mile north of Robinson Station.

N. In field, southwest of Boynton's house, section from brook toward northwest.

O. From one-half mile north of schoolhouse, on west side of Mars Hill (near Boynton's), to top of the mountain.

P. On east-west road, along north base of Mars Hill, beginning on lot 32 and extending to Maine-New Brunswick line.

1297. MONTICELLO (TOWNSHIP 8, RANGE 1).

A. Cut on Bangor and Aroostook Railroad at milepost 144 from Oldtown, 8 miles south of Harvey's.

B. Cut on Bangor and Aroostook Railroad, 1,400 feet south of milepost 144, 1 mile south of Harvey's siding.

C. Two thousand feet south of milepost 144 from Oldtown, 4.5 miles north of Monticello Station.

1298. BRIDGEWATER (TOWNSHIP 9, RANGE 1).

A. On Bangor and Aroostook Railroad, 1 mile south of Robinson Station, 1,500 feet south of milepost 154 from Oldtown.

1299. EASTON (TOWNSHIP 11, RANGE 1).

A. On Easton–Fort Fairfield road, 2 miles north of Easton Center, near fork in road at Wheeler's blacksmith shop.

B. In field east of Easton–Fort Fairfield road, 1½ miles north of Easton Center.

C. In Centerville, just north of Easton Center.

D. On road from Easton Center to Spragues Mill, one-half mile east of latter.

1385. FORT FAIRFIELD (TOWNSHIPS 12 AND 13, RANGE 1).

A. In field south of Presque Isle–Fort Fairfield road, 7 miles east of Presque Isle and 1 mile east of west line of Fort Fairfield.

B. On road running southeast from Fort Fairfield and then turning south between Johnson and Fitzherbert brooks, 2 miles from Fort Fairfield.

C. On east-west road, one-half mile east of railroad crossing, which is one-half mile north of Fairmount Station.

D. On first east-west road north of Fairmount Station, between Fort Fairfield–Easton road and Bangor and Aroostook Railroad.

1386. NEW LIMERICK AND LUDLOW (TOWNSHIP 6, RANGE 2).

A. On Carys Mill–New Limerick road, opposite middle of Nickerson Lake. Several outcrops.

B. On Carys Mill–New Limerick road, opposite western end of Nickerson Lake.

C. Outlet of Drews Lake, north side stream, just below bridge at upper mill.

D. Outlet of Drews Lake, north side stream, 10 feet east of 1386 C.

E. Outlet of Drews Lake, south side stream, on New Limerick–Linneus town line (? or in Linneus).

F. On New Limerick–Ludlow road (running along the south side of Bangor and Aroostook Railroad), 1,200 feet south of railroad crossing.

G. Cut on Bangor and Aroostook Railroad, at milepost 188 from Oldtown, 1 mile east of Ludlow Station.

H. Cut on Bangor and Aroostook Railroad, at east end switch at Titcomb's siding, 0.8 mile east of Ludlow Station.

K. Cut on Bangor and Aroostook Railroad, at milepost 120 from Oldtown, 1.2 miles west of New Limerick.

L. In field south of Bangor and Aroostook Railroad, about one-half mile east of milepost 119 from Oldtown.

1387. Presque Isle, south one-half (Township 11, Range 2).

A. Cut on Bangor and Aroostook Railroad, one-half mile south of station at Presque Isle.

B. In wagon road (Presque Isle to Houlton), three-fourths mile south of Presque Isle.

C. Side of road at sharp turn, about three-fourths mile east of Spragueville, on road leading to Houlton from Spragueville.

D. Quoggy Joe Mountain.

E. Side of road and in field just east of bridge on stream running from Quoggy Joe Lake at Spragueville.

F. In road on hill about 1½ miles northwest of Spragueville.

1388. Presque Isle, north one-half (Township 12, Range 2).

A. In road on south bank of Aroostook River, one-half mile east of Presque Isle–Mapleton town line.

B. On north Presque Isle–Ashland road, three-fourths mile northwest of Presque Isle.

C. On north Presque Isle–Ashland road, about 1½ miles northwest of Presque Isle, just east of junction with road going to center of Mapleton.

D. On Presque Isle–Ashland road (north one) about 1½ miles northwest of Presque Isle, just west of junction of road to center of Mapleton.

E. One-fourth mile east of Presque Isle–Mapleton line, on a road which turns west from north Ashland–Presque Isle road, 1½ miles northwest of Presque Isle.

H. On south of Presque Isle–Fort Fairfield road, 2 miles from Presque Isle, where road comes nearest river bank.

K. On Presque Isle–Fort Fairfield road, 3½ miles northeast of Presque Isle.

L. In field south of Presque Isle–Fort Fairfield road, one-half mile west of east Presque Isle line.

M. North bank of Aroostook River, just below covered road bridge, north of Presque Isle.

N. South bank of Aroostook River, one-fourth mile below railroad bridge, north of Presque Isle.

1389. Caribou, south one-half (Township 13, Range 2).

A. Opposite Caribou on east side of Aroostook River, at exposures below dam and fishways.

C. Southwest of Collins's milldam, on Caribou Stream, south side of stream.

D. At mouth of Madawaska River, on east side of bridge and north bank, just beyond bridge foundation.

E. At Calkins's limekiln, in lot beyond river road and a few rods from main road back of house.

F. On road from Washburn, south of Caribou Stream, near angle of road running westward in Woodland

1390. Caribou, north one-half (Township 14, Range 2).

A. Outcrops along north bend of Aroostook River, by railroad cutting beyond the village.

C. On Canton-Limestone road, east-west, on east side of Madawaska River at the bridge.

D. Near corner road from Hardwood Creek Valley, turning eastward toward Limestone.

1391. Oakfield (Township 5, Range 3).

A. Cut on Bangor and Aroostook Railroad, 1 mile east of Ashland Junction.

B. Cut on Bangor and Aroostook Railroad, 400 feet east of milepost 113, 2 miles east of Ashland Junction.

C. Cut on Bangor and Aroostook Railroad, 200 feet west of milepost 114, 2.8 miles east of Ashland Junction.

1392. Smyrna (Township 6, Range 3).

B. Cut on Bangor and Aroostook Railroad at Timony road, about 3 miles east of Ashland Junction (22 feet of west end of this cut is in 1391.)

C. On station grounds of Smyrna Mills and just south along track.

D. Cut on Bangor and Aroostook Railroad (Ashland branch), 1,000 feet south of milepost 116 from Oldtown, 3 miles north of Smyrna Mills Station. Extends to milepost 115.

E. Cut on Bangor and Aroostook Railroad (Ashland branch), one-half mile north of milepost 114 from Oldtown, $1\frac{1}{2}$ mile north of Smyrna Mills.

F. Cuts on Bangor and Aroostook Railroad (Ashland branch), just south of bridge, Smyrna Mills.

H. Cut on Bangor and Aroostook Railroad (Ashland branch), 600 feet north of road crossing at Smyrna Mills.

K. Cut on Bangor and Aroostook Railroad, 1,000 feet east of Timony road crossing.

L. Cut on Bangor and Aroostook Railroad (Ashland branch), south of milepost 117, 4 miles north of Smyrna Mills.

Q. Ludlow granite quarry.

1393. Weeksboro (Township 7, Range 3).

A. At Weeksboro Station.

B. At and near milepost 122 from Oldtown (Ashland branch), 0.8 mile south of Weeksboro.

C. Cut on Bangor and Aroostook Railroad, 1,000 feet north of milepost 118 from Oldtown (Ashland branch), 2.8 miles south of Weeksboro.

1394. Township 9, Range 3.

A. On south branch of Presque Isle, 1 mile below Ripps Dam, 12 miles south of Tweedy's in Chapman (1099 A).

1099. Chapman (Township 11, Range 3).

A. On right bank of South Branch of Presque Isle River, about 1 mile from Chapman, south line; 1 mile west of Tweedy's.

B. On road from Presque Isle to Chapman, 7 miles from Presque Isle.

C. Edmunds Hill.

D. Hill west of road along west side Chapman (Swanback road), three-fourths mile south of Mapleton line. W. H. Littlefield's farm.

E. On Swanback road at schoolhouse, one-half mile south of Alder Brook crossing.

F. End of Swanback road running along western line Chapman, $1\frac{1}{2}$ miles south of Alder Brook crossing.

G. Near top of hill, at large square house, 1 mile south of Littlefield's, on Swanback road.

H. Hobart Hill (north two-thirds of hill is in Mapleton).

1395. Mapleton (Township 12, Range 3).

A. Granite hill on lot 15, near the Aroostook River road. Locally known as Munson's granite.

B. Group of hills between the State road and the Aroostook River, 2 miles west of east Mapleton line.

1. On lot 14, a little west of granite (1395 A).
2. On southeast corner of lot 13.
3. On northeast corner of lot 23.
4. On northwest corner of lot 24.

C. Section along upper Ashland–Presque Isle road (State road), running west from Mapleton–Presque Isle line.

1. Hill just west of township line.
2. Seven hundred feet north of road, on lot 27.

1395. MAPLETON (TOWNSHIP 12, RANGE 3)—Continued.

C. Section along upper Ashland-Presque Isle road (State road), etc.—Cont'd.
   3. One thousand feet southwest from schoolhouse on lot 44.
   4. One mile west of Mapleton–Presque Isle line.
   5. One and one-half miles west of Mapleton–Presque Isle line.
   6. Seven miles west of Presque Isle, a well on Hale's farm.

D. Section on road running northeast from Mapleton Village (Balls Mills) to North Ashland–Presque Isle road.
   1. Three miles from Balls Mills, at turn in road, in field.
   2. Five hundred feet east of 1395 D, in field.
   3. In road west and in field east of road corner, $1\frac{1}{2}$ miles south of State road.

E. Section running east-west for one-fourth mile on north part of lot 89, near Presque Isle River.

F. Just west of Mapleton–Presque Isle town line, on road branching from north Ashland–Presque Isle road $1\frac{1}{2}$ miles northwest of Presque Isle.

G. On road which branches from north Presque Isle–Ashland road $2\frac{1}{2}$ miles west of Presque Isle, hill $1\frac{1}{2}$ miles long, beginning $1\frac{1}{4}$ miles east of Winslow's farm, and extending south and west.

H. Section on road which branches from Mapleton–Presque Isle road, where it crosses north branch of Presque Isle River and runs southwest to Edmunds Hill.
   1. One-fourth mile south of Mapleton road, in road and fields.
   2. Old quarry, near bank of river, on lot 111.
   3. On northeast corner lot 110, one-fourth mile north of road.
   4. One mile south of Mapleton road.

K. On south Presque Isle–Ashland road, at road junction one-third mile west of Mapleton–Presque Isle line.

L. Section on Presque Isle–Mapleton road, running west from the bridge over the north branch of the Presque Isle River to Balls Mills.
   1. In road one-eighth mile west of bridge.
   2. In road on west slope of first hill.
   3. At west base of hill.
   4. At road junction, $1\frac{1}{2}$ miles east of Balls Mills.
   5. East slope of hill, $1\frac{1}{4}$ miles east of Balls Mills.
   6. In road and in field south of road, $1\frac{1}{4}$ miles east of Balls Mills, on lot 99.
   7. At road junction, 1 mile east of Balls Mills.

M. Along the road and extending north to the river, on lots 90 and 91.

N. South half of lot 101.

O. Section on road running north-south along west side of lot 99.

P. Section running east-west across lots 106 and 107.

Q. Section on north-south road between lots 115 and 116.
   1. In road, one-half mile north of Mapleton-Chapman line.
   2. In road, 1,000 feet north of 1395 Q1.

R. Section in road which branches from Mapleton–Presque Isle road, $1\frac{1}{2}$ miles east of Balls Mills, and runs along base of hill on lot 99. Outcrops begin near Mapleton road and extend south for one-fourth mile.

1396. WASHBURN (TOWNSHIP 13, RANGE 3).

B. At mill on Salmon Brook, southeast corner of Washburn Township, north of Aroostook.

C. On road near middle of township, running northward from center.

D. On road near middle of township, running northward from center.

E. On road near middle of township, running northward from center.

F. At Washburn Ferry, north bank of Aroostook River.

1396. WASHBURN (TOWNSHIP 13, RANGE 3)—Continued.
- G. Right bank of Aroostook River, a few rods east of the Wade-Washburn town line. (Probably reaches into Wade.)
  - 2. On brow of hill in road south of and near 1396G.
- H. Three-fourths mile below Washburn Ferry, north bank of Aroostook River.
- K. North bank of Aroostook River, 1½ miles west of East Washburn line. Near 1395A.

1397. WOODLAND (TOWNSHIP 14, RANGE 3).
- A. Outcrop on road (main road from Caribou west through Woodland to Perham), a few rods west of crossing of north branch of Caribou Stream.
- C. On main road at McIntyre Hill, outcrop at corner of road running south.
- D. On main road near center of township, before reaching road running southwest.
- E. On road from center of Woodland to Washburn and about a mile south of the Caribou-Perham road, sloping to the west of Caribou Stream.
- F. Limestone outcrop along main Caribou-Woodland road, about a mile west of center of township, and on the east slopes of the valley of west branch of Caribou Stream.
- G. On road going south about a mile east of west town line, and one-half to three-fourths mile south of the Caribou-Woodland-Perham road; outcrops appearing also along main line to the Perham town line, where there is station G4.
- K. On road obliquely crossing northeast corner Woodland and direct to New Sweden, at a point 1½ miles from eastern boundary of town, and 1 mile east of crossing north branch Caribou Stream, 2 miles south of Woodland-New Sweden line.
- L. Small mill about one-fourth mile west of K.
- M. About 1¼ miles farther northwest than L, on road running along east side of North Branch Caribou Stream, and about 1 mile south of town line.
- N. On north-south road near center of town, within one-half mile of north line of town, and near crossroad.
- S. At corner of road running directly west near lower edge of Woodland Township, beyond middle westward, where road turns south.

1096. NEW SWEDEN (TOWNSHIP 15, RANGE 3).
- A. On middle road from Woodland to New Sweden, near the township line, on west side of road.
- B. Outcrop on south side of road, going down hill from post-office a few rods.
- C. Opposite Baptist Church, below post-office to the west.
- D. On road one-fourth mile west of 1096C.
- E. At corner of road turning up hill to north, about 1 mile from south line, and 1 mile east of west line of town.
- F. On north-south road, about 1½ miles north of 1096E, near middle north-south line of township, and within 1 mile of west line.
- G. On road and in field to north of road at head of Bearsley Branch, near the west line of New Sweden, outcrops extending from the main road running north-south to beyond the New Sweden line to west.
- H. On Olivenbaum farm, in northeastern part of township, in field in back part of farm. Farm facing east and west road, at summit between sources of the north branch of Bearsley Brook, and a stream running south and then westward and emptying into the outlet of Little Madawaska Lake. The farm marked by a single large pine tree, and stone pile built about its root.
- I. In road opposite Olivenbaum farm.

1096. NEW SWEDEN (TOWNSHIP 15, RANGE 3)—Continued.

J. In field south of road, east of Olivenbaum house and still on the slopes of the north branch of Bearsley Stream.

K. In field south of road, east of Olivenbaum house and still on the slopes of the north branch of Bearsley Stream.

L. On side of road running northwest from Pedersons toward Madawaska Lake, beginning opposite the dam above Pedersons, Jemtland post-office.

M. Off the main east-west road, in northern part of township, southward about middle of township, on hill on west side of Bearsley Branch.

O. Along eastern road, from corner at north where it turns toward Pedersons and Madawaska Lake to the New Sweden main east-west road, a distance of about 4 miles.

P. Along eastern road, from corner at north where it turns toward Pedersons and Madawaska Lake to the New Sweden main east-west road, a distance of about 4 miles.

Q. Passing along the north-south road in eastern New Sweden, crossing the watershed into the sources of north branch of Caribou Stream, turning corner by the mill on outcrop showing first traces of the calcareous element in the slates.

R. In picnic ground south of main east-west road from New Sweden post-office, outcrop of iron and manganese stained slates.

S. Going east on main east-west New Sweden road beyond the picnic ground corner, over a mile, on the rise from the long summit marsh, outcrops of calcareous shales.

T. At corner of road, main east-west New Sweden road, turning south, outcrops of shales.

V. On road near crossing of New Sweden–Woodland line, between the sources of Otter Brook and Hardwood Creek.

1398. ST. CROIX (TOWNSHIP 8, RANGE 4).

A. Cut on Bangor and Aroostook Railroad and falls on St. Croix River at milepost 132.

B. Cut on Bangor and Aroostook Railroad, north of milepost 131, 1 mile north of St. Croix Station.

C. Falls on St. Croix River, three-fourths mile south of St. Croix Station.

1416. GRISWOLD (TOWNSHIP 9, RANGE 4).

A. Cut on Bangor and Aroostook Railroad (Ashland branch) at mill seat, 1½ miles south of Griswold.

B. Rapids in St. Croix River at mill seat, 1½ miles south of Griswold.

1399. TOWNSHIP 11, RANGE 4.

B. Hedgehog Mountain.

1415. CASTLE HILL (TOWNSHIP 12, RANGE 4).

A. 6. Near middle of east side lot 32, on east bank of brook.
   7. In field, at corner of woods, 700 feet west of A 6.
   8. Three outcrops at large stone piles on lot 32, about halfway between A 7 and A 9.
   9. Five hundred feet north of A 10.
   10. Several exposures in field, southwest corner lot 32, at junction of roads.

B. Section along ridge in the woods on lot 31, Castle Hill.
   1. West of road (about 800 feet) and near north line of lot 31.
   2. On west brow of hill on lot 31, about east of mouth of Welts Brook.
   3. Little north of B 2.
   4. Hill on northwest corner of lot 31, or on lot 30, overlooking the river. Section is on steep northwest face.

1415. CASTLE HILL (TOWNSHIP 12, RANGE 4)—Continued.

C. All of the field occupying the southeast corner of lot 31, Castle Hill, at the junction of the State road with the road running north; south along east side of Castle Hill Mountain.
  1. Low hill occupying extreme southeast corner of lot 31.
  2. Ledge in open field north of C and directly across the road from 1415 A 9.

D. Section along the State road from where it crosses Castle Hill ridge to east line of township.
  1. On Castle Hill–Ashland road, one-half mile west of junction with north-south road east of Castle Hill Mountain, and about $1\frac{1}{2}$ miles west of Castle Hill post-office.
  2. Side of road on hill three-fourths mile west of Castle Hill Hotel.
  3. In road, one-half mile west of Castle Hill Hotel.
  4. In road, 1 mile east of Castle Hill Hotel.
  5. In road, $1\frac{1}{4}$ miles east of Castle Hill Hotel.

E. McDonalds Hill, on lots 53, 54, 55, and 78, Castle Hill.
  1. On side of hill, a little north of center of lot 54.
  2. On south brow of the main hill, mostly on lot 78.

F. Section along north-south road which branches from State road about 1 mile west of Castle Hill Hotel, and runs east of the Castle Hill–Haystack ridge.
  1. East side of road on northwest corner of lot 68.
  2. Both sides of road (and along stream on lot 79) near northwest corner of lot 80 (Turner's house).
  3. On bank of brook, near middle of west line of lot 80.

G. Section along brook, near junction of north-south and east-west roads, in lot 103 and 104, nearly all in the latter.
  1. On lot 103, west of road along east side of Castle Hill–Haystack ridge.
  2. Following down stream to east, across lot 104.

H. Footpath, beginning at Mapleton-Ashland road, 1 mile east of Haystack and running north 1 mile to junction of roads at schoolhouse, on lot 103.
  1. Low hills on southwest corner of lot 128, on east side of path.
  2. Southeast from schoolhouse and across road into lot 116.

J. Both sides of road and in fields along Ashland–Presque Isle road, $2\frac{1}{2}$ miles east of Castle Hill post-office, and just west of junction with north-south road at blacksmith shop.

K. On Dr. Dow's farm and in road near his house (Mapleton).

L. On J. W. Dudley's farm, $2\frac{1}{2}$ miles west of Mapleton Village.
  1.
  2. } In field southwest of house.
  3.
  4. In ravine west of barn, on lot 105.
  5. Along ravine running north-south, south of east-west road past Dudley's and about on line between lots 117 and 118.

M. On lower Presque Isle–Ashland road from Dr. Dow's house to 1 mile east of Haystack Mountain.

N. Haystack Mountain and immediate vicinity.

O. At junction of east-west road (Dudley's) with northwest road along east side of Welts Brook, near southwest corner of lot 102.
  1. In and north of road, at extreme southwest corner of lot 102.
  2. One-half mile north of road junction, and on west side of road, on lot 101.

P. On north of Ashland–Presque Isle road, just east of Sheridan–Castle Hill line.
  1. At schoolhouse, $1\frac{1}{2}$ miles east of Sheridan line.

R. Hill on north Ashland–Presque Isle road, 2 miles from Sheridan line.

1415. Castle Hill (Township 12, Range 4)—Continued.

S. North bank of Aroostook River, 1 mile below mouth of Beaver Brook.

T. Both sides of Aroostook River, and in stream bed at Castle Hill Mountain, between mouth of Welts Brook and Castle Hill–Wade line.

V. Section along west side of McDonalds Hill, in and near north-south road which follows east side of Welts Brook.

1. Between road and Welts Brook, at west base of McDonalds Hill.
2. In road, 700 feet south of McDonalds Hill.
3. Hill east of road and about middle of lot 90, west side of hill.

X. Outcrops on lot 89, southeast corner, included between two branches of Welts Brook and the north-south wagon road.

Y. Near east bank of Welts Brook, on south side line of lot 100, in a footpath made by continuing the Dudley road west to the brook.

Z. Group of hills to the northeast of Haystack, on lots 114, 115, 126, 127.

1. Southeast brow of Pyles Hill, lot 115.
2. On side of hill, about one-eighth mile southwest of Z 1.
3. Top of hill which forms highest point northeast of Haystack and about one-half mile from the mountain.

1417. Wade (Township 13, Range 4).

A. In road on south bank of Aroostook River, a few rods west of Wade-Washburn town line.

B. In field just north of road on south bank of Aroostook River, about one-half mile west of Wade-Washburn town line.

C. On Mr. Donelly's (?) farm, between road and south bank of Aroostook River, about 1 mile west of Wade-Washburn town line.

D. In road on south bank of Aroostook River, 2,000 feet west of 1417 C.

F. On right bank of Aroostook River, just below rips, at mouth of Gardner Creek (or Upper Salmon Brook), 1,000 feet west of 1417 G.

G. On right bank of Aroostook River, just below rips, at mouth of Gardner Creek (or Upper Salmon Brook).

H. In road running from Wade to Castle Hill (about 3 miles from eastern line of these townships), just north of Wade–Castle Hill line.

K. North bank of Aroostook River, $1\frac{1}{2}$ miles below mouth of Gardner Creek.

L. In bed of Gardner Brook, one-half mile from its mouth.

M. Little stream back of house on lot 17.

1418. Perham (Township 14, Range 4).

H. On the east-west road in northern part of Perham, about 1 mile from northern town line, and nearing the valley of the stream which is source of Salmon Branch.

1. At schoolhouse; slates.
2. On side hill of valley going down; sandstone.
4. On rise of valley on west side; sandstone.
5. One-fourth mile farther; sandstone.

1419. Madawaska Lake (Township 16, Range 4).

A. Along east shore of lake, south of Jones's cottage.

B. Beyond Jones's cottage on lake shore, outcrop of banded red and green slates; bedding seen and showing slate lying upon the sandstone of 1419 A.

1. Sandstone with round balls (concretions) in it.
2. Red and green slate lying outside it, on the shore and beyond in lake, at its edge.

1338. Township 9, Range 5.

A. Cuts on Bangor and Aroostook Railroad (Ashland branch) at milepost 140 from Oldtown, 3.7 miles south of Masardis.

B. About 5 miles southwest of Masardis, at junction of Oxbow road with one running south through 85. Same material all along road.

1337. MASARDIS (TOWNSHIP 10, RANGE 5).
- A. 1. In field north of road, three-fourths mile west of Masardis, on river bank.
  - 2. In road west of hotel on hill.
- C. On south bank of Aroostook River, near Bangor and Aroostook Railroad station, Masardis.

1098. ASHLAND (TOWNSHIP 11, RANGE 5).
- A. 1. Ashland Village, opposite Ashland Hotel.
  - 2. In Ashland Village, on road from hotel to railroad station.
  - 3. East side of road, 400 feet south of Ashland Hotel.
  - 4. On east bank of Aroostook River, just below the mouth of Big Machias, three-fourths mile above Ashland bridge.
- B. On south Ashland–Presque Isle road, about 4½ miles east of Ashland.
- C. On south Ashland–Presque Isle road, a few rods west of Ashland.
- D. On north Ashland–Presque Isle road, extending from Ashland to north Ashland town line.
- E. On Big Machias River, at milldam near mouth.
- F. On Mr. Gilman's farm, three-fourths mile south of Ashland, on Masardis road.
- H. On east-west road which branches from Masardis road, three-fourths mile south of Ashland (at Gilman's farm), in field just east of railroad crossing, just west of 1098 F.
- K. In field east of road on Winslow's farm, 1½ miles south of Ashland.
- L. 1. In road near corner, three-fourths mile northeast of railroad crossing, near milepost 152 from Oldtown, about 3½ miles south of Ashland.
  - 2. In road west of a field southwest of schoolhouse, 2 miles south of Ashland, on Masardis road.
- M. 1. In field west of road on C. G. Read's farm, 3½ miles south of Ashland.
  - 2. From newly dug well, 1½ miles north of Ashland-Masardis line, on road east of Aroostook River, one-eighth mile southeast 1098 M[1].

1097. SHERIDAN (TOWNSHIP 12, RANGE 5).
- A. On north Ashland–Presque Isle road, a few rods north of Sheridan south line.
- B. South side of north Ashland–Presque Isle road, one-fourth mile north of Sheridan south line.
- C. North side of road, a few rods east of Alder Brook, at foot of hill.
- D. In north Ashland–Presque Isle road, at top of hill, 1 mile east of Alder Brook (?).
- E. Right bank of Aroostook River, a short distance below mouth of Alder Brook.
- F. South of upper Ashland–Presque Isle road at Frenchville store and church.
- H. On right bank of Aroostook River, about 1 mile west of east Sheridan line, on Alley's farm—called "Alley's grindstone."
- K. On north Ashland–Presque Isle road, one-eighth mile west of east Sheridan line.
- L. South bank of Aroostook River, one-half mile below Ashland Mill.
- M. On south bank of Aroostook River, 1½ miles below Ashland Mill.
- N. North bank of Aroostook River, 2 miles below Ashland Mill.
- O. North bank of Aroostook River, 1½ miles below mouth of Alder Brook.
- P. Northwest bank of Aroostook River, at upper end sharp bend, 5 miles from Ashland Mill. (500 feet upstream from 1097 R.)
- R. On north bank of Aroostook River, lower end of sharp curve, 5 miles from Ashland Mill (?), three-fourths mile west of 1097 H. 500 feet east of 1097 P.
- S. South bank of Aroostook River, one-half mile above east Sheridan line.

1340. GARFIELD (TOWNSHIP 11, RANGE 6).
- A. First long hill on Ashland road, west and south along Big Machias, beginning one-fourth mile southwest of mill.

1340. GARFIELD (TOWNSHIP 11, RANGE 6)—Continued.

B. On road along Big Machias River, one-fourth mile west of fork turning south along Aroostook River.

C. On Mr. Hugh's farm, 3½ miles from Ashland, on road along the south side of Big Machias River.

D. Right bank of Big Machias River, 1 mile above mouth of Greenlow Brook.

E. On left bank and in bed of Big Machias River, about 1 mile above mouth of Greenlow Brook, west of 1340 D.

NEW BRUNSWICK.

The following stations are east of the Maine border in New Brunswick:

7. Cut on Houlton branch Canadian Pacific Railroad, 3½ miles west of Debec Junction, Carleton County.
8. On road running south from McKenzies Corner, 1 mile south of railroad crossing, Carleton County.
9. On Bemis's farm, 1 mile west of Ivys Corner, south of Debec Junction.
10. One-fourth mile south of Ivys Corner, along Pocomoonshine Creek, Carleton County.
11. On west bank of Pocomoonshine Creek, one-half mile south of Ivys Corner.
12. Cut on Canadian Pacific Railroad, one-fourth mile south of crossing of road from lower Woodstock, about 3 miles south of Debec Junction.
13. Cut on Canadian Pacific Railroad at curve, one-half mile south of Debec Junction.
14. Cut on Canadian Pacific Railroad at Teeds Mill (Topley's), between Debec Junction and Woodstock.
15. At milldam, Teeds Mill (Topley's), between Woodstock and Debec Junction.
16. Falls on Bull Creek, one-half mile below Teeds Mill (Topley's).
17. One-fourth mile below falls on Bull Creek, 1 mile below Teeds Mill (Topley's).
18. Cut on Canadian Pacific Railroad, Teeds Mill (Topley's), 300 feet north of New Brunswick 14.
19. In bed of Meduxnekeag River at Woodstock.
20. On Florenceville-Centerville road, one-half mile west of Florenceville, Carleton County.
21. On Florenceville-Centerville road, 1½ miles west of Florenceville, Carleton County.
22. On Florenceville-Centerville road, 2¼ miles west of Florenceville, Carleton County.
23. In village of Centerville, Carleton County.
24. One and one-half miles north of Florenceville, just west of corner where two churches and a schoolhouse stand.
25. On west bank of St. John River at Florenceville bridge.
26. Grand Falls.
27. Aroostook Junction, Canadian Pacific Railroad.
28. Falls on the Aroostook River, near its mouth.
29. On road running east-west along north base Mars Hill, continued one-half mile into New Brunswick.

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ADVERTISEMENT.

[Bulletin 165.]

The statute approved March 3, 1879, establishing the United States Geological Survey, contains the following provisions:

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization; and the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

Except in those cases in which an extra number of any special memoir or report has been supplied to the Survey by resolution of Congress or has been ordered by the Secretary of the Interior, this office has no copies for gratuitous distribution.

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"*Provided*, That hereafter the reports of the Geological Survey in relation to the gauging of streams and to the methods of utilizing the water resources may be printed in octavo form, not to exceed one hundred pages in length and five thousand copies in number; one thousand copies of which shall be for the official use of the Geological Survey, one thousand five hundred copies shall be delivered to the Senate, and two thousand five hundred copies shall be delivered to the House of Representatives, for distribution."

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The map sheets represent a great variety of topographic features, and with the aid of descriptive text they can be used to illustrate topographic forms. This has led to the projection of an educational series of topographic folios, for use wherever geography is taught in high schools, academies, and colleges. Of this series the first two folios have been issued, viz:

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2. Physiographic types, by Henry Gannett, 1900, folio, consisting of the following sheets and 11 pages of descriptive text: Norfolk (Va.-N. C.), a coast swamp; Marshall (Mo.), a graded river; Lexington (Nebr.), an overloaded stream; Harrisburg (Pa.), Appalachian ridges; Potean Mountain (Ark.-Ind. T.), Ozark ridges; Marshall (Ark.), Ozark Plateau; West Denver (Colo.), hogbacks; Mount Taylor (N. Mex.), volcanic peaks, plateaus, and necks; Cucamonga (Cal.), alluvial cones; Crater Lake special (Oreg.), a crater.

GEOLOGIC ATLAS OF THE UNITED STATES.

The Geologic Atlas of the United States is the final form of publication of the topographic and geologic maps. The atlas is issued in parts, or folios, progressively as the surveys are extended, and is designed ultimately to cover the entire country.

Under the plan adopted the entire area of the country is divided into small rectangular districts (designated *quadrangles*), bounded by certain meridians and parallels. The unit of survey is also the unit of publication, and the maps and descriptions of each rectangular district are issued as a folio of the Geologic Atlas.

Each folio contains topographic, geologic, economic, and structural maps, together with textual descriptions and explanations, and is designated by the name of a principal town or of a prominent natural feature within the district.

Two forms of issue have been adopted, a "library edition" and a "field edition." In both the sheets are bound between heavy paper covers, but the library copies are permanently bound, while the sheets and covers of the field copies are only temporarily wired together.

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28	Piedmont	Virginia Maryland West Va	79°–79° 30′	39°–39° 30′	925	25
29	Nevada City: Nevada City Grass Valley Banner Hill	California	121° 00′ 25″–121° 03′ 45″ 121° 01′ 35″–121° 05′ 04″ 120° 57′ 05″–121° 00′ 25″	39° 13′ 50″–39° 17′ 16″ 39° 10′ 22″–39° 13′ 50″ 39° 13′ 50″–39° 17′ 16″	11.65 12.09 11.65	50
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31	Pyramid Peak	California	120°–120° 30′	38° 30′–39°	932	25
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33	Briceville	Tennessee	84°–84° 30′	36′–36° 30′	963	25
34	Buckhannon	West Va	80°–80° 30′	38° 30′–39°	932	25
35	Gadsden	Alabama	86°–86° 30′	34°–34° 30′	986	25
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38	Butte Special	Montana	112° 29′ 30″–112° 36′ 42″	45° 59′ 28″–46° 02′ 54″	22.80	50
39	Truckee	California	120°–120° 30′	39°–39° 30′	925	25
40	Wartburg	Tennessee	84° 30′–85°	36°–36° 30′	963	25
41	Sonora	California	120°–120° 30′	37° 30′–38°	944	25
42	Nueces	Texas	100°–100° 30′	29° 30′–30°	1,035	25
43	Bidwell Bar	California	121°–121° 30′	39° 30′–40°	918	25
44	Tazewell	Virginia West Va	81° 30′–82°	37°–37° 30′	950	25
45	Boise	Idaho	116°–116° 30′	43° 30′–44°	864	25
46	Richmond	Kentucky	84°–84° 30′	37° 30′–38°	944	25
47	London	Kentucky	84°–84° 30′	37°–37° 30′	950	25
48	Tenmile District Special.	Colorado	106° 8′–106° 16′	39° 22′ 30″–39° 30′ 30″	55	25
49	Roseburg	Oregon	123°–123° 30′	43°–43° 30′	871	25
50	Holyoke	Mass Conn	72° 30′–73°	42°–42° 30′	885	50
51	Big Trees	California	120°–120° 30′	38°–38° 30′	938	25
52	Absaroka: Crandall Ishawooa	Wyoming	109° 30′–110°	44°–44° 30′	1,706	25
53	Standingstone	Tennessee	85°–85° 30′	36°–36° 30′	963	25

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Mineral Resources of the United States, 1895, David T. Day, Chief of Division. 1896. 8°. xxiii, 542 pp., 8 pl. and maps; iii, 543-1058 pp., 9-13 pl. Being Part III (in 2 vols.) of the Seventeenth Annual Report.

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